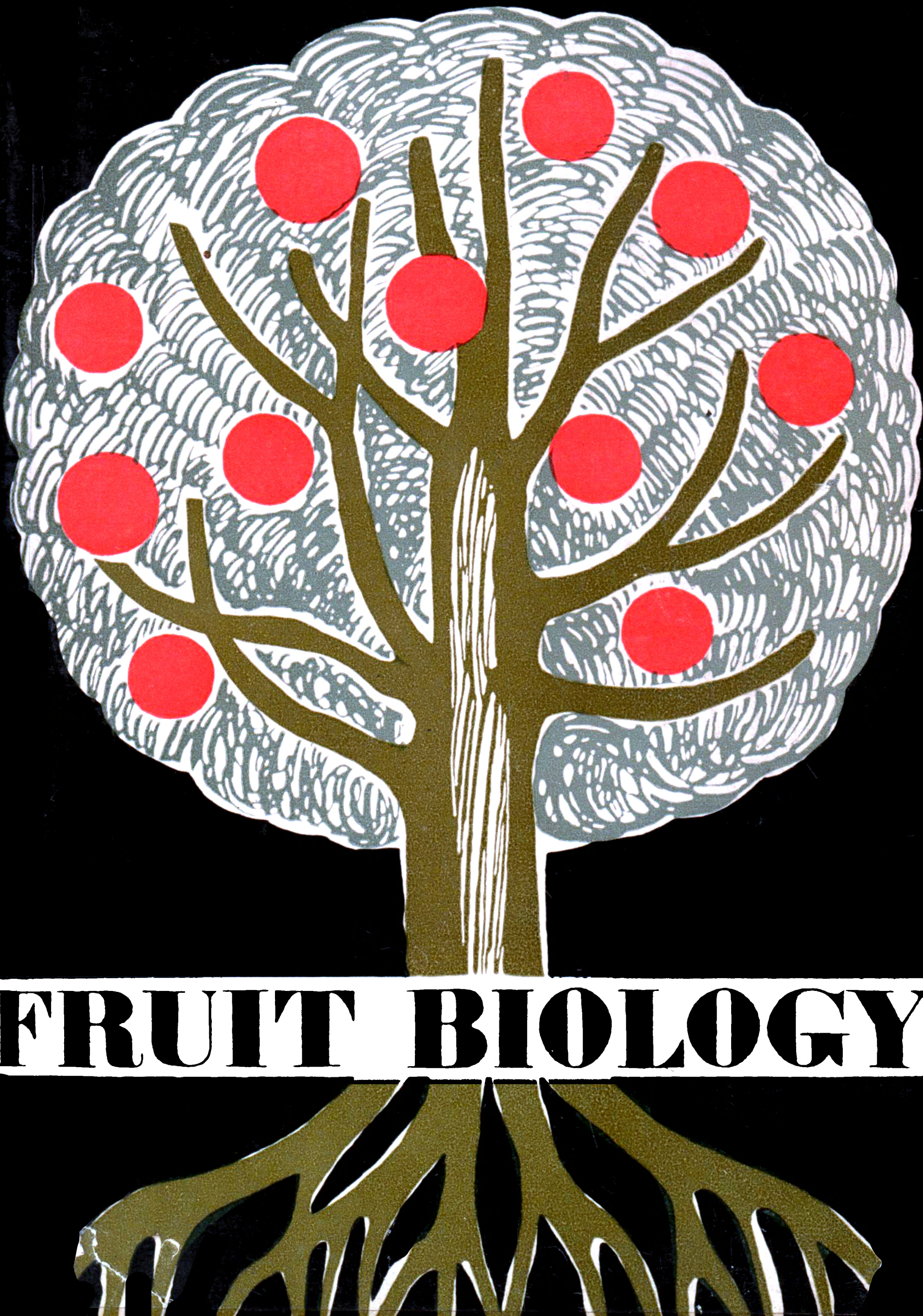
V. KOLESNIKOV



FRUIT BIOLOGY

V. A. Kolesnikov is the author of the first manual on laboratory and field methods of root studies published in Moscow in 1962 in which he summarized his 40 years of experience and made a comparative study of research methods used in the U.S.S.R. and abroad.

Side by side with research V. A. Kolesnikov has lectured at agricultural colleges as head of departments of pomology—in Krasnodar from 1927 to 1931, in Simferopol from 1932 to 1950 and in Moscow since 1951. He received his doctorate in 1947 and was elected a corresponding member of the Lenin Academy of Agricultural Sciences in 1959. Since 1952 V. A. Kolesnikov has attended all the International Horticultural Congresses.

The present book is part of a textbook on fruit growing written for Soviet agricultural colleges by a team of staff members of the department of pomology at the Timiryazev Agricultural Academy. It was edited by V. A. Kolesnikov and published in Moscow in 1959. V. A. Kolesnikov himself wrote the chapters which form the present book. In 1964, when an English translation was suggested, he brought the original material up todate.

MIR PUBLISHERS MOSCOW

V. A. Kolesnikov was an undergraduate at the Timiryazev Agricultural Academy in Moscow when he first became absorbed in the study of fruit tree roots. That was in 1920. Four years later he published the first results of his research. By then he had unearthed certain correlations in the growth of root systems. The most fruitful of these related to the average root length of seedlings which the young research worker found to be constant for each species no matter what environment it grew in. Later on he used this root coefficient to develop a new and efficient method of root study—the so-called "free monolith" method, which is now extensively used in the U.S.S.R. and in some other countries. The author has also established that new root formation is always attended by the dying off of roots, a phenomenon which he termed root shedding. The investigations conducted by the author in Moscow Region, and in subsequent years in the Crimea and Krasnodar Territories enabled him to advance a number of cultural recommendations—on under-tree ploughing, the application of fertilizers, the time of watering, etc.,

V. A. Kolesnikov is the author of the first manual on laboratory and field methods of root studies published in Moscow in 1962 in which he summarized his 40 years of experience and made a comparative study of research methods used in the U.S.S.R. and abroad.

Side by side with research V. A. Kolesnikov has lectured at agricultural colleges as head of departments of pomology—in Krasnodar from 1927 to 1931, in Simferopol from 1932 to 1950 and in Moscow since 1951. He received his doctorate in 1947 and was elected a corresponding member of the Lenin Academy of Agricultural Sciences in 1959. Since 1952 V. A. Kolesnikov has attended all the International Horticultural Congresses.

The present book is part of a textbook on fruit growing written for Soviet agricultural colleges by a team of staff members of the department of pomology at the Timiryazev Agricultural Academy. It was edited by V. A. Kolesnikov and published in Moscow in 1959. V. A. Kolesnikov himself wrote the chapters which form the present book. In 1964, when an English translation was suggested, he brought the original material up todate.

MIR PUBLISHERS MOSCOW

MIR
PUBLISHERS

В. А. КОЛЕСНИКОВ

БИОЛОГИЧЕСКИЕ ОСНОВЫ ПЛОДОВОДСТВА

На английском языке

FRUIT BIOLOGY

V. KOLESNIKOV, D.Sc.

MIR PUBLISHERS MOSCOW

UDC $570 + 634 \cdot {}^{1}/_{6}(075.8) = 20$

Translated from the Russian
by L. Kolesnikov

Contents

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

CHAPTER SEVEN

CHAPTER EIGHT

CHAPTER NINE

Preface

Students of horticulture must understand the morphological, anatomical, physiological and biochemical fundamentals of large-scale annual fruit production and the biological fundamentals of fruit plant propagation. They gain this understanding from a college course on fruit growing, especially from its major section—the biological fundamentals of fruit growing.

It is the author's considered opinion that the student must first study the morphology and anatomy of the branch and root systems of the principal fruit plants and then go over to the major fruits commercially grown in the country, at the same time covering the botanical and biological peculiarities of the more important wild fruit plants. Against this background knowledge of the wealth of fruit plant life and the economic importance of the fruit-growing industry the student studies in greater detail the ontogeny and age changes, including senescence and rejuvenation of plants, which will help him understand the laws governing the formation of the branch and root systems; he also studies the periodical phenomena of growth and development and the external factors with which the plants are in intimate interdependance. The subject is summarised in Chapter 8 in which plenty of space is devoted to the biological and biochemical fundamentals of the cultural practices, and the varietal and natural factors, which together play a decisive

role in the fulfilment of the fruit grower's main aim: to produce an abundant crop every year.

In conclusion the author thinks it appropriate to touch on research in fruits, particularly in the field of root studies, which he believes is still not receiving enough attention.

An attempt has been made not to divorce theory from practice; on the contrary, all fundamental problems are followed through to their cultural applications.

Use has been made of both foreign and Soviet literature though more space has naturally been allocated to Soviet research and, particularly, to the author's work on the roots of fruit trees.

The author is greatly indebted to Dr. F. A. Roach, Mr. D. N. Durmanov and Mr. Sharma Bal Ram for valuable suggestions and criticisms in the preparation of this book, to whom he extends his sincere thanks.

V. A. KOLESNIKOV
March 1966
Moscow

INTRODUCTION

Fruit growing as a section of the agricultural industry is called upon to supply the population with tree and soft fruits. Fruit growing as a science makes a study of the structure, growth and development of fruit plants, their propagation and cultivation and the external factors with which they are intimately connected. Consequently, the main task of fruit growing as a science is to lay the theoretical foundation on which the fruit grower could build his system of raising fruit crops according to species, variety and local conditions.

Importance of tree and soft fruits. Tree and soft fruits contain considerable quantities of sugar—of the order of 19-23 per cent in temperate-zone fruits and 55-70 per cent in certain subtropical fruits. Nuts contain plenty of oil and protein, e.g., walnut up to 75 per cent and up to 22 per cent respectively. The calory value of nut kernel is higher than that of meat, fish and bread and almost equals that of dairy butter.

Fruits, nuts and berries contain various acids, mineral and aromatic substances, as well as vitamins A_1, B_1, B_2, B_6, C, E_1, H, K_3, P and PP. The richest sources of vitamin C are unripe walnuts and the fruit of actinidia and black currant.

Winter varieties of fresh apples and pears, all nuts and frozen stone and soft fruits have a long storage life and ship well over long distances. Fruits, nuts and berries can be processed into a variety of food products: dried fruit, fruit in syrup, jam, marmalade, jelly, glazed fruit, syrup, juice, wine, etc. All this makes it possible to supply the population with the products of the fruit-growing industry all the year round.

Fruit trees and shrubs are used for green belts round cities and industrial centres, for planting wind breaks, parks, boulevards, avenues, roads, railways, ponds and for reclaiming gully-ridden land, etc.

Fruit plants are health-builders. They reduce winds, improve the composition of the air, beautify recreation centres. Almost all of the fruit plants are honey plants too.

Fruit growing is a vitally important section of the Soviet agricultural industry. This is borne out by the considerable increase in orchard acreage and gross output over the years. Before the 1917 Revolution 665,000 hectares of land were under fruits compared with 2,912,000 in 1960. Even compared to 1953, orchard territory had shown an increase of 1.97 million hectares by 1961. Between 1953 and 1961 gross output had risen by about 57 per cent, state purchases increasing by 90 per cent (I. S. Kuvshinov *et al.*, 1963). In actual figures production was 3,208,000 tons in 1953, 4,951,000 tons in 1959 and 5,978,000 tons in 1962. Thus, over the last 9 years, the output of tree and soft fruits has increased by 89 per cent inclusive of grapes and by 38 per cent excluding grapes (P. F. Dubrava, 1963).

Still the average per capita production of all fruits in the U.S.S.R. in 1962 and 1963 was only 24.4 kilograms. This was largely due to the bulk of commercial orchards being still young or at least not yet of the maximum production age.

According to the U.S.S.R. Academy of Medical Sciences, the annual human diet should include about 100 kg of fruit. And this is what the Soviet fruit-growing industry is aiming at with its current programme of expansion.

A short history of fruit growing. To judge from the pictures of fruits and plants on Egyptian pyramids and other ancient monuments, fruit plants have been in cultivation since earliest times. From two to five thousand years ago fruit trees were cultivated on the present Soviet territory in Central Asia (Ferghana and Sogdiana) and Armenia (Urartu), and also in Syria, Mesopotamia and Egypt.

The earliest descriptions of orchards found refer to Babylon and Assyria (3000 B. C.), China (2000 B. C.), India (1280 B. C.), the Crimea (700 B. C.), Greece (300-400 B. C.) and at the turn of our era to Rome, in the writings of Cato, Varro, Columella, Plinius and Virgil.

Many authorities list olive, pomegranate, apple, pear, plum, peach and apricot as the most ancient fruits in cultivation.

Tree and soft fruits are mostly grown in the temperate, subtropical and tropical zones.

At present there are over 30 million hectares under fruits in the world. The leading species are grapes (9 million hectares), olives (6 million hectares), apples (3.5 million hectares) and citrus fruits (1.5 million). The largest orchard acreages are in the U.S.S.R., U.S.A., Spain, France and Italy.

Soviet fruit growing yesterday and today. In Kiev Rus fruit growing developed in the 10th century in monasteries and on princes' estates. When Moscow was founded in the 12th century, fruit growing was already flourishing in those parts. However, there were no commercial orchards in the feudal period. It wasn't until the 19th century ushered in capitalism in Russia that fruit growing became an industry, especially in the Crimea, the Volga area, the Ukraine and Turkestan in Central Asia.

Due to popular breeding effort a number of outstanding apple varieties were developed such as Antonovka, Anis, Grushovka Moskovskaya and Borovinka in Central Russia, the Sinap in the Crimea, Sary Tursh and Jir Haji in Azerbaijan, Kekhura in Georgia, and also apricots, sour cherries and peaches. These high-yielding varieties are extensively cultivated to this day.

Areas of commercial fruit growing have emerged, specializing for certain fruits and varieties, e.g., Antonovka-type varieties in the central zone of the European part of the U.S.S.R., Anis-type in the Volga area, Sinap-type in the Crimea, apricots for drying in Central Asia, plums in the Sochi district of the Krasnodar Territory, pears in the Alushta district of the Crimea, sweet cherries in the Melitopol district of the Ukraine.

A great contribution to the development of Russian fruit growing, particularly in the south, was made by importations of high-quality European varieties of apple, pear, sweet cherry, plum and peach.

The science of fruit growing and research work in this field were neglected in tsarist Russia. The few experimental stations that existed—13 altogether, with those at Tashkent, Sukhumi and the Salgyr in the Crimea among the

better known ones—were all set up as late as the turn of the present century.

Russian fruit growing as a science was greatly contributed to by A. T. Bolotov, I. V. Michurin, M. V. Rytov, R. I. Shreder, L. P. Simirenko, V. V. Pashkevich, A. S. Grebnitsky, N. I. Kichunov, T. K. Kvaratskhelia and P. G. Schitt. However, the overall backwardness of tsarist Russia, the poor development of her rail and road transport, and the absence of fruit freezing and processing facilities hampered the development of her fruit-growing industry. In 1887, when the first-ever orchard survey took place in Russia, there were 444,400 hectares of land under fruits within the present boundaries of the U.S.S.R. By 1917, the orchard territory had reached 665,000 hectares. Most of the orchards were in the south, the central zone being next in importance. In Siberia there were virtually no commercial orchards.

After the Great October Socialist Revolution a programme of large-scale socialist agriculture was launched and collective and state farms set up.

The socialist reconstruction of agriculture coupled with capital investment, the growth of mechanisation and the use of better management and the latest scientific achievements have provided a boost for the development of fruit growing. Thus, for instance, the average annual increment in orchard territory during the first two five-year-plan periods (1928-1937) was 70,600 hectares which was nine times as great as for the same period immediately before the Revolution. In 1940, the area under tree and soft fruits reached 1,400,000 hectares. However, the harsh winters of 1939-1940, 1941-1942 and 1954-1955, and the fact that a part of the U.S.S.R. was temporarily occupied during the Second World War resulted in a severe setback for the Soviet fruit-growing industry—the destruction of about 300,000 hectares of orchards.

In the post-war years, following a number of Government decisions, the fruit-growing industry was rapidly rebuilt and further developed.

Table 1 gives an idea of the present state of the Soviet fruit-growing industry.

It can be seen from this table that by 1963 the total territory under fruits had reached 3,302,000 hectares of which 1,319,000 hectares were in full production, as compared to 925,000 hectares in 1953. This means that the orchard

Table 1

Distribution of Orchards and Per Capita Production of Fruit in the U.S.S.R.

(after P. F. Dubrava, 1963)

Republics	Territory as on January 1, 1963 (,000 hectares)					Average annual per capita production in 1961-1962 (kilograms)		
	tree and soft fruits	vineyards	total	percentages of the arable	per 100 persons(hectares)	tree and soft fruits	grapes	total
U.S.S.R.	3301.9	1042.0	4343.9	1.92	19.5	13.0	11.4	24.4
R.S.F.S.R.	1161.7	173.8	1335.5	0.98	10.7	6.7	. 3.0	9.7
Ukrainian S.S.R.	1228.2	353.9	1582.1	4.6	36.1	23.1	13.3	36.4
Byelorussian S.S.R.	149.9	—	149.9	2.4	17.8	14.2	—	14.2
Uzbek S.S.R.	123.8	47.8	171.6	5.3	18.7	15.2	20.0	35.2
Kazakh S.S.R.	54.3	13.5	67.8	0.2	6.4	4.1	2.6	6.7
Georgian S.S.R.	118.5	92.3	210.8	21.4	45.0	60.3	80	140.3
Azerbaijan S.S.R.	73.7	59.7	133.4	9.2	31.3	18.6	24.6	43.2
Lithuanian S.S.R.	39.3	—	39.3	1.4	13.5	11.3	—	11.3
Moldavian S.S.R.	182.1	238.1	420.2	22.3	135.5	52.9	213.6	266.5
Latvian S.S.R.	38.1	—	38.1	2.2	17.4	7.7	—	7.7
Kirghiz S.S.R.	28.9	4.6	33.5	2.8	14.5	13.8	4.1	17.9
Tajik S.S.R.	49.0	14.7	63.7	8.6	31.4	41.6	20.1	61.7
Armenian S.S.R.	28.3	34.8	63.1	12.5	31.8	24.9	85.7	110.6
Turkmenian S.S.R.	11.0	8.8	19.8	3.9	11.8	7.0	20.2	27.2
Estonian S.S.R.	15.1	—	15.1	1.8	12.1	9.6	—	9.6

Table 2

Production of Tree and Soft Fruits in the U.S.S.R.
(from I.S. Kuvshinov *et al.*, 1963)

	1913	1953	1958	1959	1960	1965 (as planned)
Territory under fruits (,000 hectares)	655	1638	2405	2653	2912	4700-4800
Yields (tons)	—	16.3	24.5	23.7	—	37-40
Total output (,000 tons)	—	2151	3078	3189	3036	7000
State purchases (,000 tons)	—	606	857	846	866*	—

*1961 figure

territory has increased by more than five times since 1913 and by 100 per cent since 1953 (P. F. Dubrava, 1963).

The following table gives additional figures on fruit growing in the period of 1913-1965.

Orchard acreages have increased, everywhere, especially in the Urals, Siberia and the Far East where over 85,000 hectares are under fruits now, as compared to a mere 600 hectares before 1917. A similar increase has been registered by the Georgian citrus-fruit industry which expanded from 160 hectares in 1913 to 9,750 hectares in 1960.

There are quite a few collective and state farms which have planted orchards of 100 hectares and more. Thus, the orchard of the Sad-Gigant state farm in the Slavyansky district of Krasnodar Territory occupies 2,151 hectares and that of the Lenin collective farm in the Slobodzeisky district in Moldavia, 1,374 hectares.

According to the type of ownership, the Soviet orchards in 1957 were: collective farms, 988,000 hectares; state farms, 175,300; individual ownership by collective farmers, 950,500; individual and collective ownership by industrial and office workers, 520,800 hectares.

Good progress is being made by individual and cooperative orchards owned by industrial and office workers. Cooperative orchards nowadays are a common sight throughout the countryside.

In 1958, planting material for the entire fruit-growing industry was provided by 900 specialized state nurseries and over 2,000 collective farms.

The various types of fruit-growing zones, from the Arctic to the subtropical, are represented in the U.S.S.R. with a total of over 50 fruits grown. In 1952, fruits accounted for 98.2 per cent and berries for 1.8 per cent. The pome fruits (apple, pear and quince) took up 54.4 per cent; the stone fruits (sour cherry, plum, apricot, peach and sweet cherry) 40.2 per cent; the nuts (filbert, almond, walnut and pistachio) 2.9 per cent; the subtropical (olive, fig, pomegranate and persimmon) and citrus fruits (mandarin, lemon and orange) 0.7 per cent; and the berries (strawberry, raspberry, currant and gooseberry) 1.8 per cent. Smaller territories were under medlar, rowan, Cornelian cherry, pecan, sweet chestnut, feijoa, avocado, grapefruit, actinidia and mulberry.

The most widespread fruits are apples, sour cherries and plums with 32.9, 27.4 and 18.0 per cent of the total orchard acreage respectively.

The Transcaucasian republics (Georgia, Azerbaijan, and Armenia) grow mostly stone fruits, particularly peach and plum. A total of 33 per cent of the nuts and 78 per cent of citrus fruits are also located in these republics.

The Central Asian republics (Uzbekistan, Tajikistan, Kirghizia, Turkmenia and the southern part of Kazakhstan) produce 72 per cent of all the dried fruit in the U.S.S.R., notably dried apricot. They also account for 50.4 per cent of all land under peaches and 30 per cent under apricots. The principal fruits in the Urals and Siberia are apples (about 65 per cent) and soft fruits (30 per cent) while the sour cherry and plum account only for 5 per cent.

In the U.S.S.R. a great deal of attention is devoted to the training of horticulturists and to development of research and breeding in fruit growing.

I. V. Michurin, a pioneer of tree and soft fruit selection and breeding in the U.S.S.R., originated many top-quality varieties, notably of apples, sour cherries and pears which are now grown on something like 10,000 hectares.

Since the establishment of the Soviet Union the country's plant breeders have developed about 1,000 varieties of tree and soft fruits. Most of them are top-quality, early-maturing, hardy varieties.

Soviet plant breeders are trying to push up the northern border of certain fruit species. They are introducing sweet cherry into Byelorussia and the Leningrad Region, apricot into the Voronezh Region, cobnut and filbert into the Tambov and other regions of the central-chernozem belt, peach into the Kiev Region, etc. In recent years new hardy large-fruited apples have been bred in the Urals and Siberia.

What of the future? The figures in Table 1 show that such republics as Moldavia, Georgia and Armenia are already producing over 100 kilograms of fruit per head of population. So are the Daghestan Autonomous Republic, the Crimean and Vinnitsa Regions of the Ukraine, the Tashkent Region in Uzbekistan, the Krasnodar Territory in the Russian Federation.

However, the overall figures of yields and total production for the entire country are still not satisfactory.

The decisions of the 22nd Congress of the C.P.S.U. held in 1962 envisaged an increase in fruit production of 470 per cent in the coming 10 years and of over 900 per cent in the subsequent 10-year period. This means that the fruit-growing industry faces the task of still greater expansion of orchard acreages, and considerable increase in yields.

It is essential to improve systems of management in tree and soft fruit production, to elaborate sound fertilizer programmes and to tailor tree care to the specific climate, soil and other conditions of the given zone.

Of vital importance is the distribution of the fruit-growing industry according to the climatic and economic zones with due account of the conditions of each region and territory. In this connection orchards will be expanded in the Ukrainian and Moldavian Republics, in Northern Caucasus and the Volga area, in the republics of Central Asia, Transcaucasia, the Urals, Siberia and the Far East, in Byelorussia and the Baltic Republics, and in the southeast of the non-chernozem and the central-chernozem zones of the Russian Federation.

Mountainous areas are to be more extensively used for planting new orchards. As it is, mountain fruit growing ac-

counts for between 15 and 20 per cent of the country's total acreage. This figure includes many orchards in Armenia, Georgia, Daghestan, Tajikistan, southern Kazakhstan and Krasnodar Territory. The most effective technique on slopes of over 10° is by terracing, which makes it possible to mechanise the entire production cycle and at the same time successfully combat erosion.

More use should be made of dwarfing stock to establish orchards earlier and obtain better-quality fruit. Fruits on such stock can be planted either in separate blocks or as filler trees in the rows or even between the rows.

More land should be planted to mandarins, oranges, grapefruits and lemons both outdoors in Georgia and in unheated trenches in Tajikistan and Uzbekistan. More lemons can be produced under glass with the use of industrial heat waste.

To achieve a quick expansion in orchard territory the collective and state farms require considerable quantities of planting material. Therefore it is the task of the nurseries to step up production.

A number of other measures are required to develop commercial fruit growing, including the setting up of more plant protection stations, stricter quarantine for the imported planting material, production of the most efficient pesticides, construction of new spraying machinery and greater use of aviation in orchard pest and disease control.

It is most essential to organise the quantity production of sorting and grading equipment and to install the modern packing, storage and processing facilities in all large orchards. The experience of many state and collective farms shows that on-the-farm processing of fruit is economically advisable.

More attention should be given to compilation and analysis of the production indices of the fruit-growing industry. This will reveal the latent possibilities for increasing the economic importance of this industry.

The training of horticulturists should be radically improved.

In the years to come science will make an even greater contribution to the development of fruit growing in the U.S.S.R. The problems that are facing the scientists are numerous: to investigate the causes and suggest the practical means of eliminating alternate fruit bearing; to breed new

varieties with a more pronounced annual bearing habit and resistance to adverse conditions; to find ways and means of increasing frost-, drought- and disease resistance of fruit crops; to find means of regulating growth, development and cropping; to intensify experimental work on frost damage prevention; to probe deeper into the fundamental and practical aspects of fruit plant nutrition; to elaborate new, more efficient fruit handling, storage and processing techniques.

CHAPTER ONE

•

MORPHOLOGICAL AND ANATOMICAL FEATURES OF FRUIT PLANTS

Tree and soft fruits have travelled a long way of evolutionary development. Together with the whole organism their heredity was shaped environmentally; new characters were fixed and then passed on to new generations.

Having lived for centuries in different environments and possessing different abilities for adaptation the fruit plants have each developed their own habit of the root and shoot systems and their own relationship with the environmental conditions in which they live. This has led, for instance, to fruit plants having root systems very different as to their size and distribution in the soil horizons. All these inherited characters are rather conservative and change but little when a plant is placed in a new environment. Yet this conservatism in the behaviour of roots and shoots in new natural or cultural conditions varies considerably from plant to plant. In this chapter, a broad description is given of the morphology and anatomy of the root and shoot systems of fruit plants.

Depending on size, longevity and certain morphological characters the fruit plants are grouped as follows:

(1) *trees with a powerfully developed stem*, such as pecan, walnut, sweet chestnut, pear, sweet cherry, and, in certain respects, apple;

(2) *trees with a less developed stem*, such as apple, quince, apricot, persimmon, plum and the tree-like varieties of sour cherry;

(3) *shrub-like trees*, such as sour cherry and plum varieties, peach, filbert, pomegranate, fig and Cornelian cherry, which all, except peach and plum, form a shrub with several main stems;

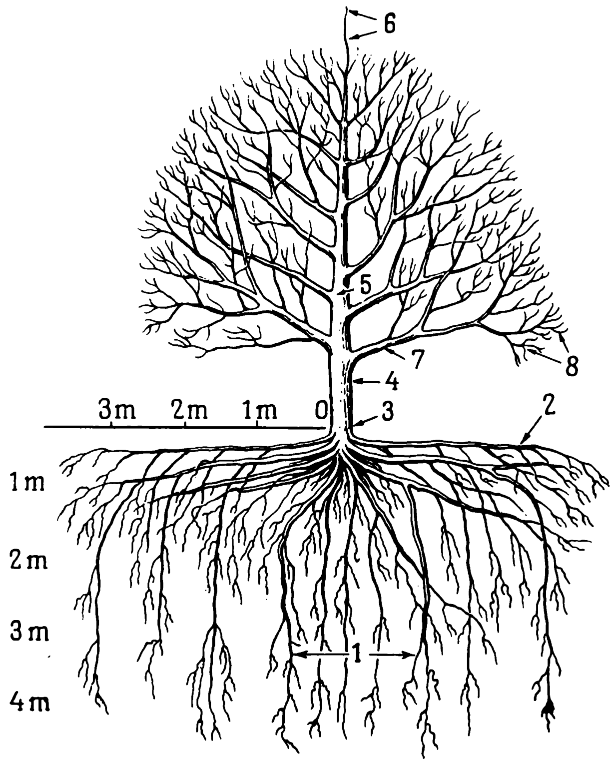


Fig. 1. Major parts of a fruit tree:
1—vertical roots; *2*—horizontal roots; *3*—root collar; *4*—trunk; *5*—stem; *6*—central leader; *7*—main branches; *8*—laterals

(4) *shrubs*, such as gooseberry and the currants forming a shrub with several stems;

(5) *semishrubs*, or *brambles*, such as raspberry;

(6) *vines*, such as actinidia, schizandra and the grapevine;

(7) *the herbacious perennials*, such as strawberry and cranberry.

In height the fruit plants are very variable: from 50-60 m (the pecan) down to 1-3 m (the shrubs, such as the currants) and even lower (the creeping strawberry and cranberry).

In longevity the fruit plants are also very variable. For instance, the olive and the sweet chestnut in the most

favourable natural conditions live till the age of 1,000 or more years; the walnut and the pecan live for 100-300 years; the apple, the pear, the persimmon, the avocado, 50-100 years; the sweet cherry, the fig, the apricot, 30-70 years; the plum, the peach, the pomegranate, 20-40 years; the currants, the raspberry and the gooseberry, 25-30 years, and the strawberry, 4-5 years.

All fruit plants possess three main vegetative organs: the *roots*, the *stem* and the *leaves*. The other parts of the plant—branches, buds, flowers, etc.—are all metamorphoses of the main organs. The fruit plants possess developed root and shoot systems (Fig.1).

Root System

Due to the very large number of families, genera, species, varieties and rootstocks which make up the tree and soft fruits and nuts now in cultivation their root systems are characterized by an amazing variety in structure, size, etc. In the course of development the roots of the fruit plants were differentiated as well as their aboveground organs, which led to the emergence of certain types of root systems different in their morphological, anatomical, physiological and other characters. It is essential, therefore, to know these types and their origin as well as a general classification of fruit plant roots.

Types of root systems. There are three types of root systems of fruit plants:

(1) root systems of *generative origin*. This type is characteristic of the overwhelming majority of tree fruits which are budded or grafted on the root system of stocks grown from seed (seedlings);

(2) root systems of *vegetative origin*. This type is characteristic of: a) soft fruits, e.g., strawberry, currants and gooseberry, and b) subtropical fruits, e.g., olive, fig, pomegranate and lemon, which root from layers or runners (strawberry), or stem cuttings; all of them also termed own-rooted plants; c) tree fruits (apples grafted on Paradise or other clonal rootstocks, and pears on quince) whose root systems have developed from vegetatively propagated layers and cuttings, i.e., clonal rootstocks, and not seedlings;

(3) root systems of *vegetative origin*, but, as distinct from type 2, having developed from stem, or suckers growing

out of the roots of the parent plant; this type is characteristic of certain varieties of sour cherry, plum, and raspberry.

Each of these types of root systems has its own peculiarities of structure, distribution and biology. For instance, the roots of seedling trees or trees budded or grafted on seedling stocks invariably reach deeper in the soil than those of the same varieties and sorts of stem origin (own-rooted) or grafted on vegetatively-propagated stocks.

Depending on *size* (length and thickness) the roots are grouped as follows:

(1) *main* or *scaffold roots*, which are long (between 0.3 and 14 m) and thick (up to 10 or more cm), and include roots of zero order (the primary root), as well as roots of first, second, sometimes, third and fourth orders of branching;*

(2) *fibrous roots*, which are short (between fractions of mm and several cm) and thin (up to 3 mm), and include roots of third, fourth and higher orders of branching.

Depending on the type of distribution in the soil the roots are grouped as follows:

(1) *horizontal roots* growing more or less parallel to the soil surface;

(2) *vertical roots* or "sinkers" growing straight downwards, along earthworm holes and soil cracks, and reaching as deep as 6 to 12 m.

All tree and soft fruits have both horizontal and vertical roots, which seem to serve different plant needs.

The horizontal roots spread over a large area of soil where microorganisms are most active and accumulation of nutrient substances—nitrogen and mineral salts—proceeds on the greatest scale.

The vertical roots serve to anchor the tree in the soil, to conduct water and, apparently, obtain certain other elements (trace elements), rare but indispensable, from the deeper soil horizons where, besides, active root growth proceeds longer than in the horizons closer to the surface.

Roots are also distinguished as *main*, *lateral*, *fibrous*, and *adventitious*. Only a seedling can have a primary root which develops from the radicle of the seed embryo (Fig. 2). Adventitious roots develop on stem-cuttings, layers and, in general, on parts of the stems of tree and soft fruits.

---

* First-order roots arise from the primary root, second-order roots from the first-order roots, etc.

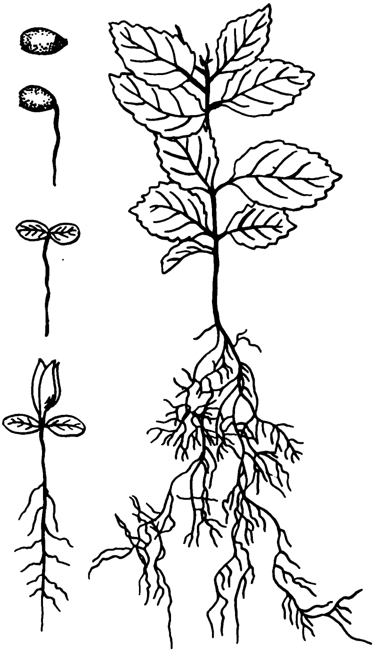


Fig. 2. Young apple tree, showing root system

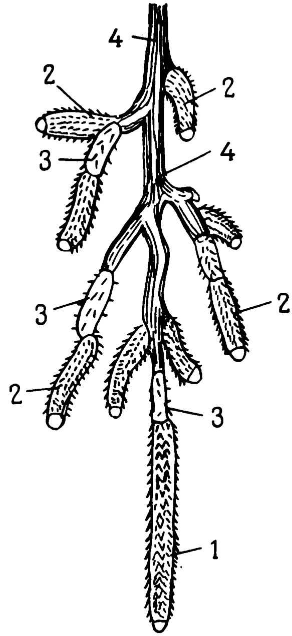


Fig. 3. Fibrous roots of an apple tree: (magnified 3.5 times)

1—growing, or axial roots; *2*—absorbing, or active roots; *3*—intermediate; *4*—conducting roots

Depending on morphological and anatomical structure and functions the fibrous roots are divided into four types (Fig. 3): (1) *growing*, or *axial*; (2) *absorbing*, or *active*; (3) *intermediate*, and (4) *conducting*.

I. *The growing*, or *axial roots* are of primary structure, white in colour, with a large meristemic zone and an ability to absorb.

Their main function is to claim new volumes of soil for the root system and to produce lateral branchings—the absorbing roots. The growing roots are considerably less numerous than the absorbing roots, but they grow more rapidly and are thicker and longer. They are analogous to shoots in the head of the tree and are produced by all

fruit plants, spring being the period of most active growth. They have no mycorrhiza.

2. *The absorbing*, or *active roots*. They are also called "feeding" roots. These roots are also of primary structure and white colour. Their main function is to absorb water and mineral substances from the soil and to transform them into organic compounds. The absorbing roots are capable of high physiological activity. In periods of active root growth they form the greatest proportion of the root system, accounting for 90 or even more per cent of the total number of roots on a plant; they number tens of thousands in seedlings and millions in mature trees. Though they average about 3.5 mm in length with 0.3-1 mm in thickness, their overall length in mature apple trees may reach several kilometres. The absorbing roots may have mycorrhiza. They usually do not develop secondary growth and are short-lived (15 to 25 days), rotting away, or "self-thinning".

I. A. Muromtsev (1963) studied in detail the sequence of tissue development in secondary growth of growing and absorbing roots and established that there are two types of the process involved, which he called synchronous and asynchronous. He based his division on the ontomorphogenetic and anatomic peculiarities observed.

In the synchronous type, the cambium and the cork-producing layer, called cork cambium or phellogen, arise beneath the primary cortex of a growing or absorbing root and begin functioning simultaneously or almost simultaneously, after which the cortex atrophies quite rapidly and is shed, as is the case in apple, pear, quince, sour cherry, plum, peach and apricot. The life of primary cortex is normally from 12 to 30 days.

In the asynchronous type, the phellogen is developed some time after the cambium. In some species, such as walnut, filbert and sweet chestnut, only 3 to 10 days intervene between cambium formation and phellogen formation, while in others, such as strawberry, raspberry, dewberry, avocado, and lemon, this period reaches 30-100 or more days. In the latter group the primary cortex functions for a long time and atrophies only after a considerable growth of the root and following cork formation. In persimmon, the primary cortex dies off prior to phellogen activity. The two types of root structure transformation are linked by intermediary forms.

3. *The intermediate roots* are of primary structure, light-grey in colour, sometimes with a lilac tinge, as in apples. Most of them are former absorbing roots about to atrophy in the process of self-thinning; the rest are growing roots about to change to secondary structure to become conducting roots. The presence of intermediate roots is a good indicator in assessing the stage of root growth: it shows that the root system has been active at least for one to three weeks.

4. *The conducting roots* are of secondary structure, light- to dark-brown in colour. They usually arise from the growing roots whose primary cortex has atrophied and been supplanted by secondary cortex, after which they grow thicker and thicker every year until they become lateral or main roots. Their function is to conduct water and nutrients in both directions, as well as to anchor the plant.

Anatomically, the growing and absorbing roots consist of a *root-cap*, a cell division and cell elongation region (*apical meristem*) and an absorption zone, or *piliferous layer*, covered with root hairs invisible to the naked eye. These are followed by a region of dying root hairs and suberized cells—an intermediate zone—and by a conducting region where the root becomes solely conducting. This latter part at first has a greyish colour but after the sloughing-off of primary cortical matter and the development of secondary cortex, the phelloderm, (Figs. 4 and 5), it turns brown.

V. Büsgen (1902) observed "knotted" roots or roots of irregular thickness. L.A. Ivanov (1916) described in pine up to 3-4 such knots on the growing roots and up to 8-9 on the absorbing roots, the latter being more pronounced. The same, up to 3-4 knots, was established for the apple tree (Ye. V. Kolesnikov, 1954). The depressed areas are brought about by a temporary worsening of the conditions for apical root growth, while thickening is due to optimum conditions. When developing secondary thickening the roots throw off the dead cortical matter together with the knots.

The horizontal and vertical roots of fruit trees have certain differences in their anatomy. In the case of oak and apple trees, I.I. Onishchenko (1955) described these differences as follows: "The large vessels of the secondary xylem in roots lying at a depth of 220-225 cm are 3 to 5

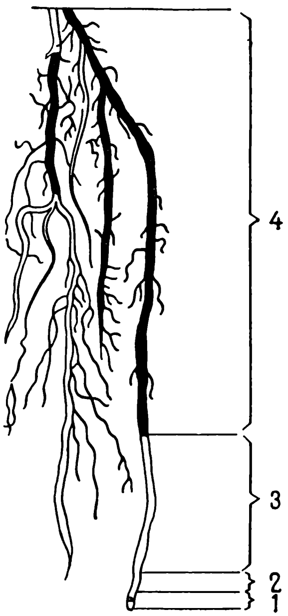


Fig. 4. Root of an apple tree:
1—root-cap; *2*—cell division and cell elongation region; *3*—absorption region; *4*—conducting region

times thicker than in roots lying close to surface. At a depth of 150 cm and particularly 200-250 cm the root loses its typical structure, showing considerable xylem deformation." In general, it can be said that the deeper the roots the bigger their tissue cells.

Root hairs. A root hair is a tubular outgrowth of the outer wall of a cell in the epidermis of the absorbing zone of the root. It is a cell in itself and has a protoplasm with a nucleus. Its cell wall is very thin, which facilitates water intake.

I.A. Muromtsev (1948) and the present author (1958) established the presence of root hairs in practically all tree and soft fruits, viz., apples, pears, quinces, juneberries, rowan-trees, sour cherries, plums, apricots, peaches, gooseberries, currants, raspberries, strawberries, grapevines, mulberries and lemons. No root hairs were found in avocado.

The root hairs combined increase the absorbing surface of the root systems of fruit plants by 2 to 6 or more times. I. A. Muromtsev (1948, 1962, 1963) found that a one-year-old Anis apple seedling develops by the end of October over

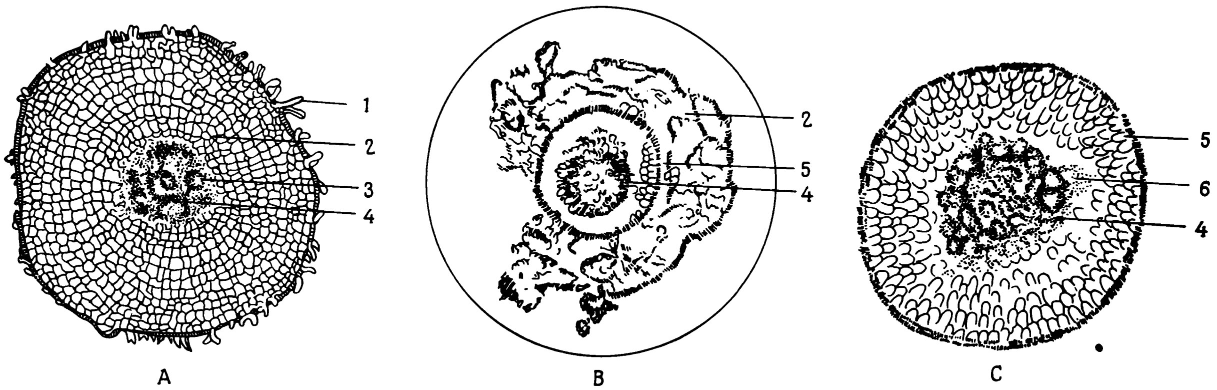


Fig. 5. Secondary growth of roots:

A—apple root of primary structure;
B—dying off of primary cortex;
C—root of secondary structure;
1—root hairs; *2*—primary cortex;
3—pericycle; *4*—central cylinder;
5—periderm; *6*—vessels of secondary xylem (highly magnified); (after I. A. Muromtsev)

17 million root hairs with a total length of about 3 km. The length of individual root hairs of apple trees raised in a humid chamber in laboratory conditions was: *M. prunifolia* L.—328 microns (up to 600 in several cases); the wild apple —216; the Siberian crab apple—196; the Doucin III—101; the Doucin V—92; the Paradise VIII—62 and the Paradise IX—61 microns. The diameter of root hairs averages 12 microns.

For the length of root hairs in different species see Table 3.

Table 3

Length of Root Hairs in Fruit Plants
(microns)

Species	Range of length observed	Predominant length
Apple (various species)	60-750	—
Wild apple	140-260	180-240
Pear (various species)	50-235	—
Ussurian pear . . .	50-80	60-70
Sour cherry	380-520	400-450
Mahaleb cherry	400-560	450-500
Plum	280-340	300
Peach	240-600	350-450
Strawberry	750-1200	1200
Raspberry	140-270	180-210
Black currant	380-500	400
Grape-vine	240-360	300
Fig	200-460	260-400
Lemon	45-60	50

I.A. Muromtsev divided the primary root of an apple seedling from base to tip into 3 mm long portions and found that the number of root hairs was respectively: 400, 500, 475, 325, 300, 300, and 300 per sq mm of surface, 500 thus being the maximum of root hair density. The tip of the root (the last 3 mm portion) had no root hairs.

Field examination of Sievers' apple (*M. Sieversii* Pop.) root hairs showed an average length of 81.6 microns and a maximum length of 163.6 microns (A. P. Dragavtsev, 1952), while the figures established by W. S. Rogers (1939) for ap-

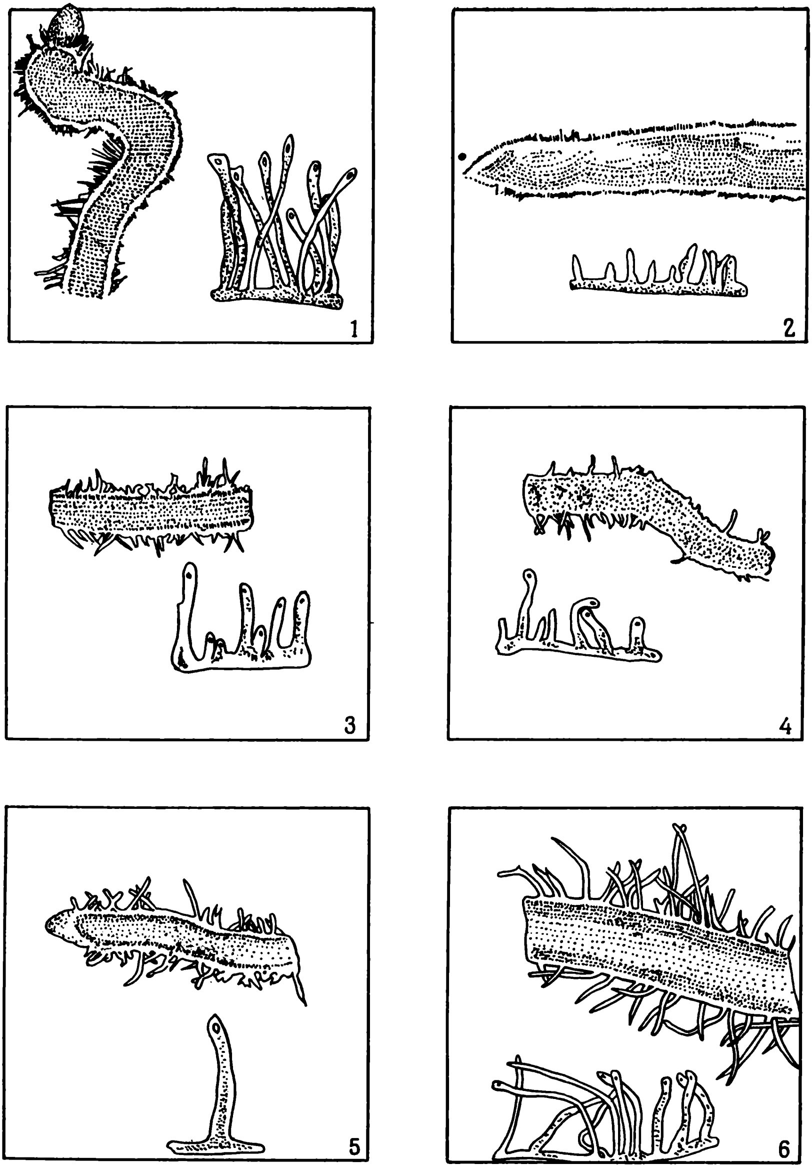


Fig. 6. Absorbing roots (the thicker ones) and root hairs (highly magnified, root hairs more so):

1—*M. sylvestris*; *2*—wild pear; *3*—hazel; *4*—plum; *5*—raspberry; *6*—currant

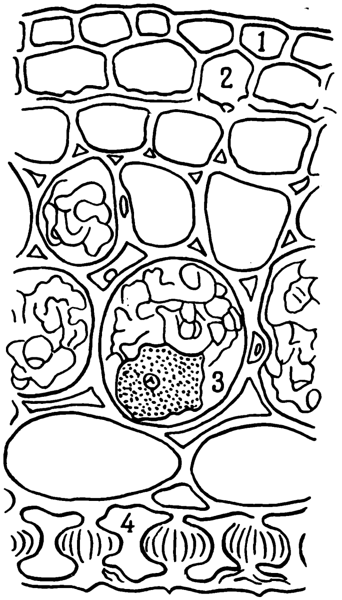


Fig. 7. Mycorrhiza of a wild sweet cherry:

1-2—rhizodermis, root hairs are absent; *3*—root cells filled with fungal hyphae in the state of decomposition; a nucleus is visible; *4*—Ф-shaped cells with endodermis cells immediately below; (after T. Dominik and S. Jagodzinski)

ple trees were in the range of 25-50 microns on clayey loams with a maximum of 75 microns.

According to data obtained by the author, the absorbing roots and root hairs of fruit plants are variable in form, length and thickness (Fig. 6.)

Root hairs live for 18 days in apples, 26 days in quinces, from 10 to 40 days in grapes (depending on the order of branching and time of formation) and from 10-27 to 190-320 days in strawberries (depending on time of formation) (I. A. Muromtsev, 1962).

The rhizosphere, mycorrhiza or root fungus. A special microflora develops in the immediate vicinity of active roots, consisting of hyphae of soil fungi living inside or just outside the root. Physiologically the soil fungi are classed in three groups: symbionts, saprophytes and parasites. The mycorrhizal fungi belong to the first group. The following types of mycorrhiza are distinguished: ectotrophic (mycelium is external), endotrophic (mycelium within cortex cells of root), endoectotrophic (intermediate), peritrophic

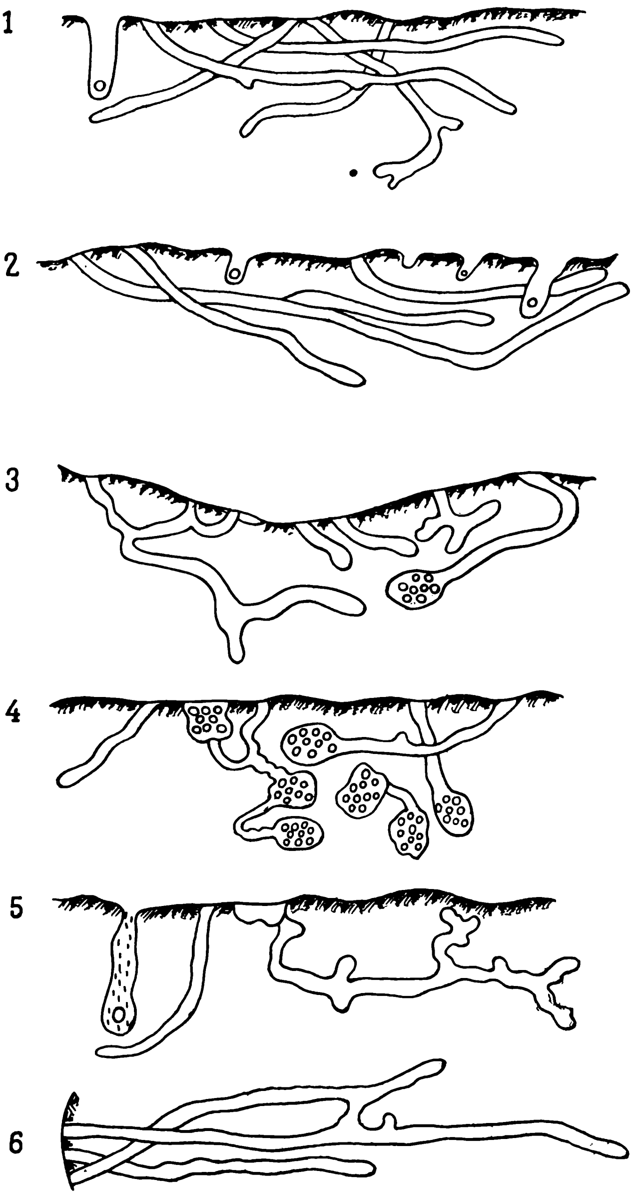


Fig. 8. Mycorrhiza of fruit plants:

1—*M. sylvestris*; *2*—wild pear; *3*—hazel nut; *4*—Skorospelka Krasnaya plum; *5*—Kaliningradskaya raspberry; *6*—Kent currant

(in the vicinity of the root) and a pseudo-mycorrhiza. The arborescent plants usually have ectotrophic and intermediate mycorrhiza (Fig. 7).

Most researchers agree that mycorrhiza constitutes a useful symbiotic association for higher plants, but opinions differ as to the exact nature of this usefulness.

Mycorrhiza occurs on pome fruits (apple, pear, quince), stone fruits (sour cherry, plum), nuts (hazel, almond, walnut, chestnut, pecan), subtropical fruits (persimmon), citrus fruits and all berried fruits (B. Vital, 1910; T. A. Dominik and S. Jagodzinski, 1946; V. A. Kolesnikov, 1955, etc.). Apples, pears, hazel nuts, sour cherries, plums and berried fruits have both mycorrhiza and root hairs (Fig. 8).

According to data obtained by L. A. Ivanov (1953), the growing roots are free of mycorrhiza, which makes for vigorous extension growth of the root system.

Mycorrhiza develops when moisture is at an optimum level. A decrease in moisture leads to the killing of mycorrhizas after which, if moisture increases, new absorbing roots appear and with them new mycorrhiza.

Not infrequently mycorrhiza is found on roots at considerable depths.

Aerial Portion

Pomologically, the aerial portion of the tree has the following main divisions (Fig. 1):

(1) *the stem*, the main upright part of the top system carrying the head of the tree;

(2) *the trunk*, the lower part of the stem from root collar to first (lowest) main branch;

(3) *the central leader*, the part of the stem above the trunk from the first branch to the base of current season's growth;

(4) *the extension shoot* or *leader*, the current season's terminal growth on the central leader;

(5) *the main branches* or *limbs*, the biggest branches of the tree making up its framework; branches arising from the trunk of a tree are known as *primary*, as distinct from branches arising directly from the primary branches which are known as *secondary*;

(6) *the head of the tree* or *crown*, the upper part of a tree which bears the branches and leaves; it may have different

shape (spreading, round, pyramidal, etc.) depending on variety, rootstock, tree age, environment and management;

(7) *the root crown* or *collar*, the point of juncture of stem and root. It may be *genuine* (typical) or *conditional*. A genuine root collar is characteristic of a seedling tree or a tree budded or grafted on a seedling rootstock. A conditional root collar is that of an orchard tree raised either from a stem cutting, layer or root sucker, or of a scion budded or grafted on vegetatively-propagated stock, e.g., on a stem cutting or layer of the Paradise, Doucin apple or quince.

Vegetative and fruiting growths. The main branches usually bear numerous growth and fruit formations having different characters and names for pome and stone fruits.

The *pome fruits* have the following vegetative and fruiting growths.

1. *The shoot*, a stem which is one year old, or less. It is called a leader, or extension shoot if it has been selected to extend the branch framework of a tree, or a maiden lateral if it is a side shoot.

In pome fruits, shoots as a rule bear no fruit buds.

Shoots arise from terminal buds on the previous year's growth; at their base they have scars which mark the place of attachment of the protective bud scales, the so-called *scar rings*. These annual rings help to determine the age of branches or even trees.

2. *The "premature" shoots*, young lateral growths which have developed in summer from the lateral buds of a shoot in its first year.

Premature shoots are a rare occurrence with the pome fruits but are often developed by the stone fruits, particularly by sour cherries and plums.

3. *The water sprouts*, vertically growing shoots arising from dormant and adventitious buds on old wood (owing to old age, hard pruning, breakage, etc.). They have long internodes and large leaves. In time, if their growth is impeded or they are clipped, they become ordinary branches.

4. *The brindilles*, thin lateral shoots about 7-30 cm long usually ending in a fruit bud. Normally they are thinner and bend more easily than vegetative shoots (Fig. 9).

5. *The dard*, a short lateral shoot, not more than 5-10 cm long, usually ending in a fruit bud. They are straight, some-

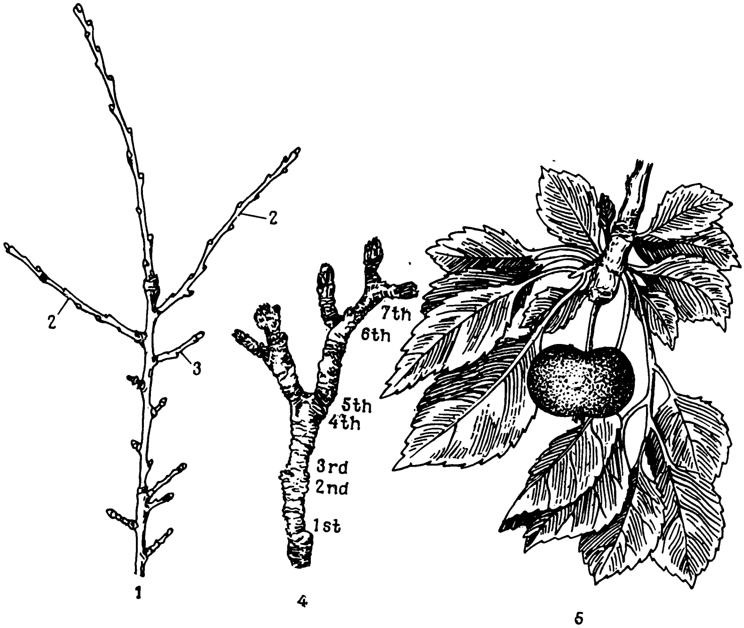


Fig. 9. Fruiting and vegetative growths of apple tree:
1—three-year-old fruiting branch;
2—brindille; *3*—dard; *4*—seven-year-old spur system; *5*—fruit and leaves on spur

what thicker at the base than at the tip and have shortened internodes and very closely spaced lateral buds.

6. *The spur*, a short lateral branch with the nodes close together often largely consisting of successive bourses (see below). One-year-old spurs are from 2-3 mm to 2-3 cm long, with rudimentary lateral buds and ending in a well-developed wood or fruit bud. They occur below dards at right angles to the branch.

7. *The spur system* or *compound spur*, is a short compound fruiting branch made up of several spurs.

As a rule, fruit spurs and spur systems increase in length slowly being covered from year to year by ring-shaped scars where closely spaced bud scales and leaf petioles were once attached. These annual rings help to make a fair estimate of the age of a fruit spur. This is most essential, for good

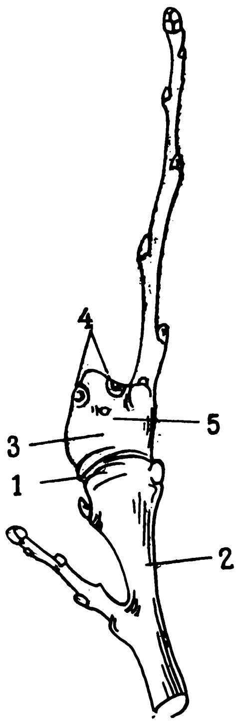


Fig. 10. Apple bourse with growth:

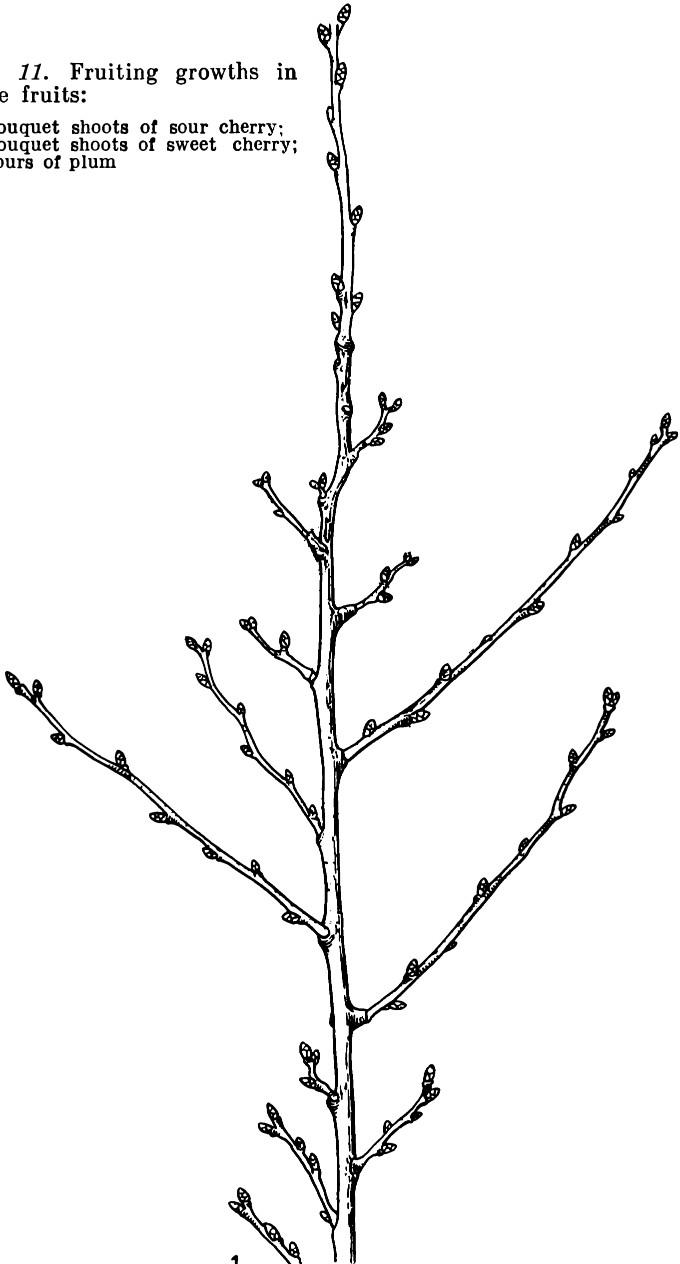
1—outer annual ring; *2*—last year's shoot; *3*—bourse; *4*—marks of attachment of fruit stem (large scars); *5*—marks of attachment of flowers or dropped ovaries

fruiting can usually be expected from six to ten-year-old spurs, while spur systems of 10 to 15 or more years old mostly just flower or bear poor-quality fruit. Besides being unproductive, such flowering entails unnecessary expenditure of nutrients and is, therefore, remedied by thinning out to encourage new growth to form.

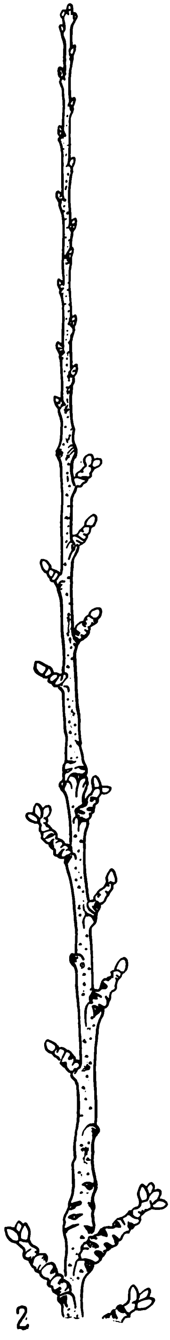
Finally, there are *bourses* which are swollen stems at the base of the inflorescence in pome fruits. They are persistent and may carry fruit or wood buds. They are formed of phloem tissue swollen by the food material stored in it and are particularly large in pears and certain apple varieties (Fig. 10). The bourses retain marks where fruit and even flowers and ovaries were attached years ago, by which the quality and quantity of the previous years' cropping as well as tree care can be assessed.

Fig. 11. Fruiting growths in stone fruits:

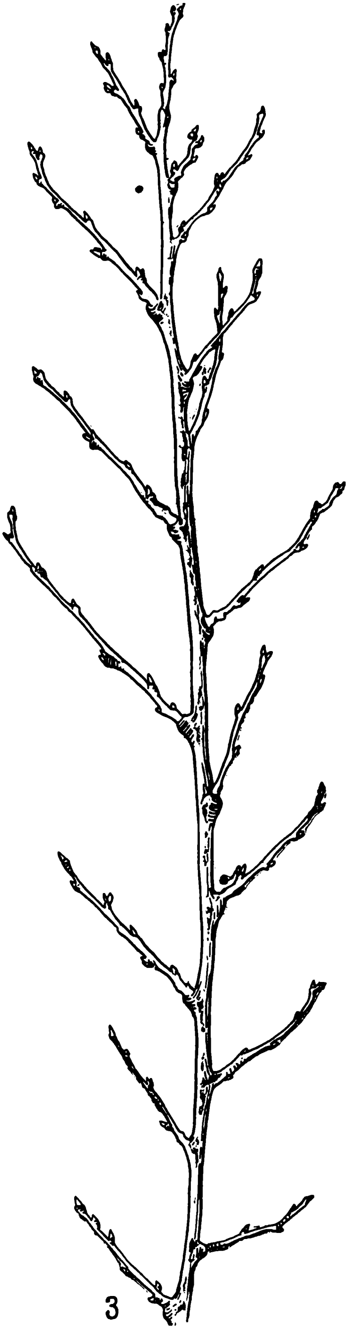
1—bouquet shoots of sour cherry;
2—bouquet shoots of sweet cherry;
3—spurs of plum



1



2



3

The stone fruits have the following formations:

(1-3) *the shoots*, *the premature shoots* and *water sprouts.* Morphologically these are similar to those in the pome fruits;

(4) *fruiting branches*, growths of the previous year. They are covered all along their length by fruit buds and end in a wood bud; in the shrub-like sour cherry varieties they are from 10 to 40 or more cm long and in the tree-like ones, from 10 to 15 cm;

(5) *mixed shoots and branches* on which fruit and wood buds alternate all along their length; such twigs occur particularly often on well-manured trees;

(6) *bouquet branches*, shortened fruiting branches 0.5 to 3 cm long, ending in a cluster of buds, of which 1 or 2 are wood buds and 4 to 10 fruit buds. They are characteristic of the sour cherry, the Ussurian plum (these have longer bouquet branches, from 2 to 3 cm) and the sweet cherry (from 2 to 10 cm). In their second season, the fruit buds produce flowers and fruits while the terminal vegetative bud gives rise to a new bouquet shoot. Bouquet shoots of the sour cherry live for 3-6 years and those of the sweet cherry for 5-10 years (Fig. 11).

(7) *the dards*, short fruiting shoots in European plum and apricot varieties from 0.5 to 8-10 cm long. The dards of plum may end in a thorn; they live from 2 to 5 years.

It must be emphasised here that no clear-cut distinction can be drawn between fruiting and vegetative growths of a tree, since changes in conditions may induce a fruit spur to develop into a large branch or a maiden lateral may be spur pruned into fruiting wood.

The branches of many fruit plants bear certain other growths known as:

(1) *the thorns* or *spines*—these are protective formations of stem origin; they are short modified branches arising in the axils of leaves and characteristic of apple, pear, plum, blackthorn, myrobolan, plum, apricot, etc.;

(2) *the prickles*—these are multicellular excrescences of the bark as in gooseberry, or of the epidermis as in raspberry.

The buds. Fruit plants have *vegetative* or *wood* buds (also called *growth buds*) ensuring the development of the branch system of the tree and *reproductive*, or *fruit buds* (also called *blossom buds*), from which flowers and then fruits develop.

Fig. 12. Buds of apple tree:

1—fruit bud; *2*—wood bud (terminal or apical); *3*—wood bud (axillary)

The vegetative and reproductive buds vary in structure, size, shape and position. In general, reproductive buds are larger and plumper than vegetative buds. What are called *normal* buds start into growth the year following their formation, as distinct from *dormant* or *latent* buds that may not become active until years later.

The vegetative buds may be borne either terminally, at the tip of a shoot, in which case they are called *terminal* or *apical*, or on the sides of a shoot, when they are known as *lateral* buds. In the same way, the reproductive buds may be borne either terminally, at the tips of shoots, as in apples and pears (in most varieties which in consequence are known as tip-bearers), quinces, olives (in some varieties), and nuts (the female flowers), or on the sides of shoots, as in all stone fruits, nuts (the male flowers), subtropical fruits, soft fruits, and in apples and pears (sometimes).

The vegetative or wood buds may be of the following types: (1) terminal; (2) axillary; (3) dormant and (4) adventitious.

1. *The terminal* or *apical buds* terminate growing branches and the shoots on them. Upon development such

a bud gives rise to a shoot with internodes and leaves again terminating in a wood bud (Fig. 12).

2. *The axillary buds* are situated in the axils of leaves of all leaf-bearing branches and shoots. As a rule three buds arise in a leaf axil, out of which one or two are blind and hidden in the bark of the shoot or branch. The better developed axillary buds are located in the middle part of shoots or higher in apples, pears and quinces, in the lower part in currants and gooseberries and at the base in raspberries. Some of the stone fruits develop wood buds collaterally with fruit buds in the same leaf axil.

3. *The dormant buds* occur in the axils of leaves and, in most varieties, at the base of every stem. They are recognised by minute size and few embryo leaves, and are sometimes practically invisible. They may remain dormant for a long time growing slightly every year due to terminal growth of the shoot (by no more than the increase in shoot girth). The dormant buds of apples and pears may remain alive tens of years, those of sweet cherries, plums, apricots and particularly of peaches and sour cherries being less viable. They may start into vigorous growth and produce a shoot through some stimulation such as pruning, heavy leaf damage, normal-bud damage, etc.

4. *The adventitious buds* are poorly if at all differentiated bud initials that may arise anywhere outside the axils of leaves. Due to some change in conditions such as freezing injury, severe pruning or breakage, or to propagation of currants, gooseberries, quinces, figs, olives, etc., by cuttings, such buds are capable of producing shoots. Adventitious buds also originate on the roots of sour cherries, plums and apples and on the callus on root cuttings. On the ability of most fruit plants to produce adventitious buds depend vegetative propagation, tree shaping and pruning.

The reproductive or fruit buds are of three types: 1) simple, 2) mixed, and 3) multiple.

1. *The simple buds* arise on the sides of vegetative or fruiting wood and contain only embryo flowers; they are characteristic of the stone fruits, the walnut and the filbert nut (the male flowers), and of red and white currants and lemons.

2. *The mixed buds* are borne either terminally or axillary on fruiting wood and contain not only reproductive

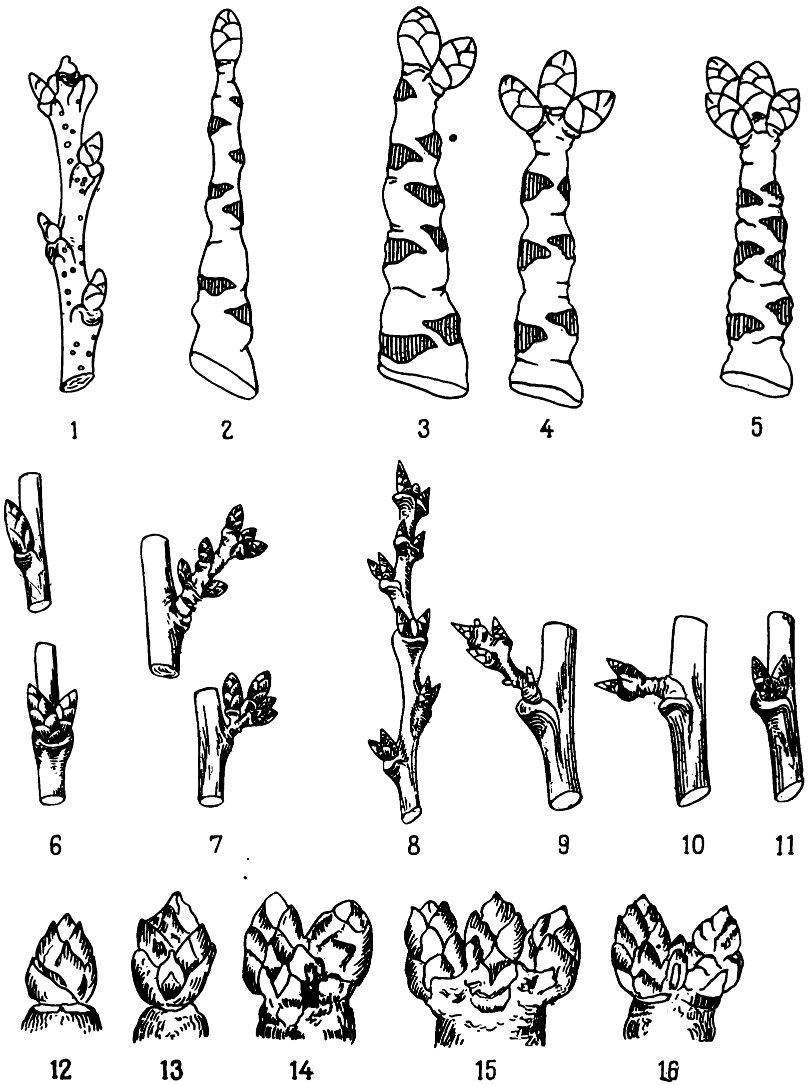


Fig. 13. Types of fruit buds:

1-5—sweet cherry; *6-7*—sour cherry;
8-11—plum; *12-16*—peach (wood bud, fruit bud, twins, triplets, two fruit buds with a wood bud in between)

but also vegetative parts and leaf initials; they are characteristic of the pome fruits, and of raspberries, black currants, gooseberries, persimmon, fig, walnut, sweet chestnut and filbert (the female flowers).

3. *The multiple buds.* These are double and triple buds that occur in the leaf axils of some stone fruits (sometimes only in certain varieties) in the following combinations: one wood bud and one fruit bud, two fruit buds with one wood bud in between, two and, rarely, three fruit buds (Fig. 13). The best combination is a triplet, with a wood bud between two fruit buds, which produces both fruits and leaves; in this case normal supply of nutritive substances is ensured. When only fruit buds arise on a maiden lateral, which sometimes occurs in peaches, such a shoot is removed as unfruitful, the practice being known as disbudding.

Multiple buds are characteristic of peaches, almonds, and apricots, and of some varieties of shrubby sour cherries, e.g., Vladimirskaya and Lyubskaya, the Ussurian and several European plums, e.g., Ochakovskaya and Skorospelka Krasnaya.

It should be remembered that in the main no clear-cut distinction can be drawn between vegetative and reproductive buds, since in certain conditions vegetative buds can develop into reproductive buds.

Anatomical features of vegetative and fruiting growths. A transverse section through a shoot or branch will show on examination the following main parts or tissues:

(1) outer part—bark covered with cork tissue;

(2) middle part—wood or xylem;

(3) cambium—the thinnest layer of tissues between bark and wood.

The cambium, or lateral meristem, consists of thin-walled elongated living cells rich in protoplasm and containing a large nucleus. Every year all stems increase in girth through division of cambium cells, which cut off new cells (bigger in spring and smaller in autumn) on both tangential faces, the cells towards the centre differentiating into xylem (wood) elements and the cells towards the outside into phloem (inner bark or bast) elements. Thus the wood and bast tissues are connected all along the stem in cylinder arrangement, which allows for quick conduction of water and nutritive substances upwards,

mainly through the xylem vessels and tracheids, and downwards through the phloem sieve tubes.

Besides, all stems have the so-called medullary rays, consisting of a few layers of living parenchyma cells, which transverse all annual rings from pith to cortex at right angles to the axis. Along these rays water and nutritive substances are conducted from pith to cortex and backwards. The ray tissues, just as the other tissues of the stem, can serve as storage of food reserves (starch, sugar and fat).

As fruit trees grow annually, their stems increasing in girth, the active wood-cambium-bast tissues, which they retain all their lives produce the annual growth rings.

The student must learn to distinguish cambium, wood and bark because the fruit grower deals with them daily, in pruning, in budding and grafting, and in general tree care.

The cambium produces wood and bark and constitutes the actively dividing part of the stem. That is why in cases of partial or even total destruction of bark and/or wood the stem may survive through the activity of a live cambium engendering new xylem and phloem tissue. And that is also why proper tree care with particular emphasis on good feeding is so essential, for the better the tree care the greater the number of layers of cambium cells—this building up the tree's resistance against adverse conditions and making for quicker healing of wounds inflicted in pruning and by pests and diseases.

It has been established that as a shoot develops into fruiting wood its anatomy greatly changes, viz., the amount of its living, unlignified phloem tissues increases while that of xylem tissues decreases.

The more phloem tissues the fruiting branches develop the more food reserves they have, since these tissues are better equipped for storage. Besides, the normally shortened fruiting branches have considerably more leaves per length unit than the vegetative shoots. This explains how useful anatomical and morphological analysis is not only in fundamental work but also in the day-to-day work of the fruit grower, who deals with outer and inner tree tissues when pruning, healing wounds, etc.

In its initial stage of development the shoot is green in colour. At this time its girth increases by division of the

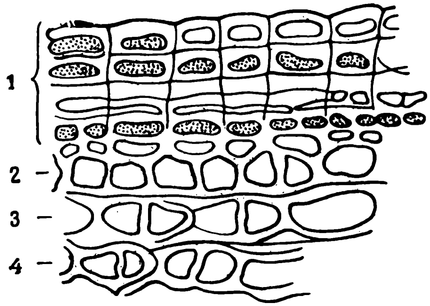


Fig. 14. Transverse section of the periderm of apple tree:

1—cork layer; *2*—cork cambium or phellogen; *3*—phelloderm; *4*—collenchima

epidermal cells. After a few weeks the epidermis is split and its cells, as for instance in apples, or cells contiguous to it, give rise to a secondary meristem known as the *cork cambium*, or *phellogen*. This forms secondary protective tissue, the *cork*. The cork cambium persists in some fruit trees and in others, e.g., apples and pears, is usually replaced by a new layer of cork cambium lying deeper in the cork. This new meristem produces new layers of cork, with the result that all the tissues lying external to them eventually die off and are shed in the form of bark, either entirely or in scales or strips which are carefully removed.

The three layers that eventually result, namely, an outer phellem or cork layer, the middle active phellogen and an inner phelloderm or secondary cortex are called the *periderm* (Fig. 14), which the fruit grower is careful to keep intact when removing dead cortical matter off the tree. The cork layer of the periderm sheathes the trunk and all the branches of the tree protecting it from wounds and damage by fungous and bacterial pests and diseases.

Young shoots transpire water, for which purpose their tough epidermis has a large number of narrow intercellular pores known as *stomata*. The trunk and branches of a tree bear numerous *lenticels* perforating the periderm whose function, like stomata in the leaves, is to facilitate aeration of the internal tissues.

Stomata can be seen only through a microscope while lenticels can be picked out as pin-point outgrowths of a slightly different colour than the surrounding bark. When dead cork is sloughed off new lenticels develop. So the fruit grower is well advised to keep clean the bark on his

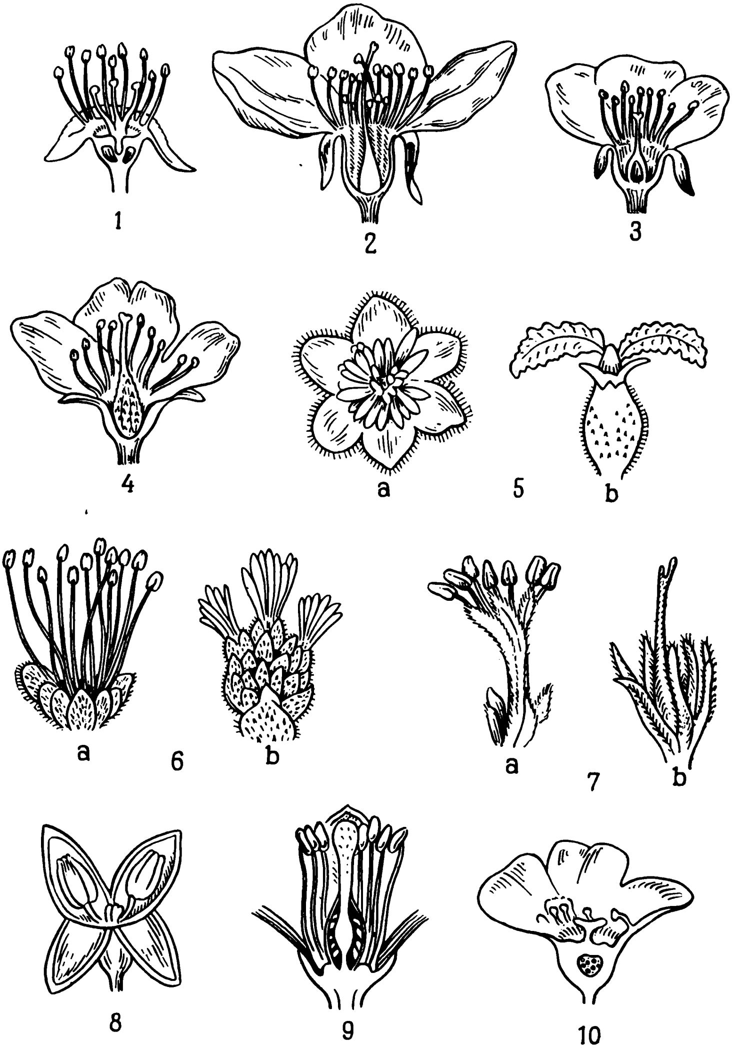


Fig. 15. Types of flowers:

1—apple; *2*—sour cherry; *3*—plum;
4—almond; *5*—walnut; *a*—male, and *b*—female flower (highly magnified); *6*—sweet chestnut: *a*—male, and *b*—female flower (highly magnified); *7*—fig: *a*—male, and *b*—female flower (highly magnified); *8*—olive; *9*—lemon; *10*—currant

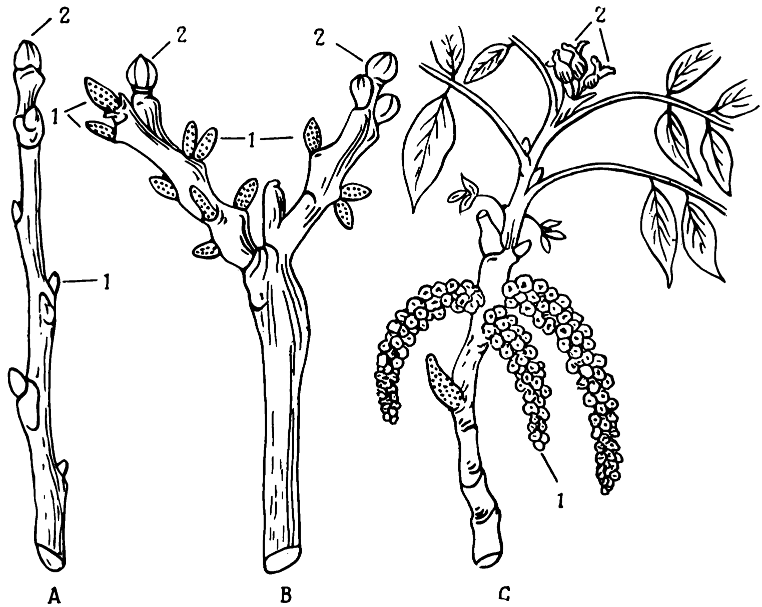


Fig. 16. Vegetative and fruiting growths of walnut:

A—one-year-old growth: *1*—wood buds, *2*—fruit buds; *B*—fruiting branch: *1*—male inflorescences (catkins) at dormant stage; *2*—female flower buds; *C*—branch with flowers: *1*—male flowers; *2*—female catkins

trees, remove in time dead tissues and in case of a wound never put off healing it.

Floral morphology. The flower is the characteristic reproductive organ of all flowering plants. Depending on structure and functions of flowers and their principal parts—the male (stamens) and the female (pistils)—and their mutual position, the flowers of fruit plants are divided into *bisexual* or *hermaphrodite* (known also as *perfect*) and *unisexual* or *diclinious.*

When both stamens and pistils occur in the same flower such flowers are termed *bisexual.* They are characteristic of most fruit plants: all pome, stone and subtropical fruits except persimmon, and all citrus and berried fruits except Hautbois. The bisexual flowers are usually entomophilous, i.e., pollinated by insects (Fig. 15).

When stamens and pistils occur in separate flowers such flowers are *unisexual* and are called *male* (*staminate*) or *female* (*pistillate*) accordingly. If male and female flowers are on the same plant but in different inflorescences such plants are called *monoecious* and if the sexes are separated into inflorescences on different plants such plants are called *dioecious*.

The monoecious species include the nut trees such as filbert, walnut, pistachio, sweet chestnut and pecan. All of them are anemophilous, i.e., pollinated by the wind (Fig. 16). The dioecious species include the Hautbois and the fig, both entomophilous.

There are *transitional groups* of species, e.g., persimmon, which have trees with the predominance of either pistillate or staminate flowers. Then there is an *intermediate group* of species, e.g., mulberry, in which both monoecious and dioecious plants occur. Both persimmon and mulberry are entomophilous plants.

The fruit buds of tree or soft fruits contain one to several flowers, the latter gathered in clusters or *inflorescences*. Some inflorescences are known by special names.

One flower is contained in the buds of quinces, peaches, apricots, almonds.

Two, *three* or *more flowers* are contained in the buds of plums, walnuts, filberts, sweet chestnuts (only female flowers).

The umbel is the inflorescence of apples, sour cherries and sweet cherries. The fruit buds of apples, according to the author's data obtained from 38 varieties, produce 3 to 8 flowers.

The corymb is the inflorescence of pears, rowans, hawthorns. The fruit buds of pears, according to the author's data obtained from 29 varieties, produce from 3 to 11 flowers.

The raceme is the inflorescence of bird-cherry, mahaleb cherry, gooseberries, currants, raspberry, olive.

The panicle is the inflorescence of the avocado.

The catkin is the inflorescence of filbert, walnut, pecan, sweet chestnut. They may be very long, e.g., 20 cm in the chestnut, and have many male flowers.

The dichasium is the inflorescence of strawberry.

Knowledge of flower morphology is essential, particularly when planting pollinators together with female-

flowered plants such as Hautbois, fig, persimmon and mulberry.

Morphology and anatomy of fruits. In some plants the fruit is developed only from the ovary of a single flower; such fruits are said to be *true*. In other plants, other floral parts such as the receptacle and perianth may enter into the formation of the fruit producing what is known as a *false fruit* or *pseudocarp*. In still other plants the flowers have several or many pistils forming several fruitlets which combined are referred to as an *aggregate fruit*. Finally, there are still more complicated false fruits in which a whole inflorescence forms a single but complicated fruit. These are referred to as *infructescences* or *inflorescent* fruits.

1. *The true fruits* are berries and drupes.

The berry is formed from a monocarpellary or syncarpous ovary containing one or more seeds. The pericarp is juicy, often brightly coloured. Examples of berries are currant, gooseberry and persimmon.

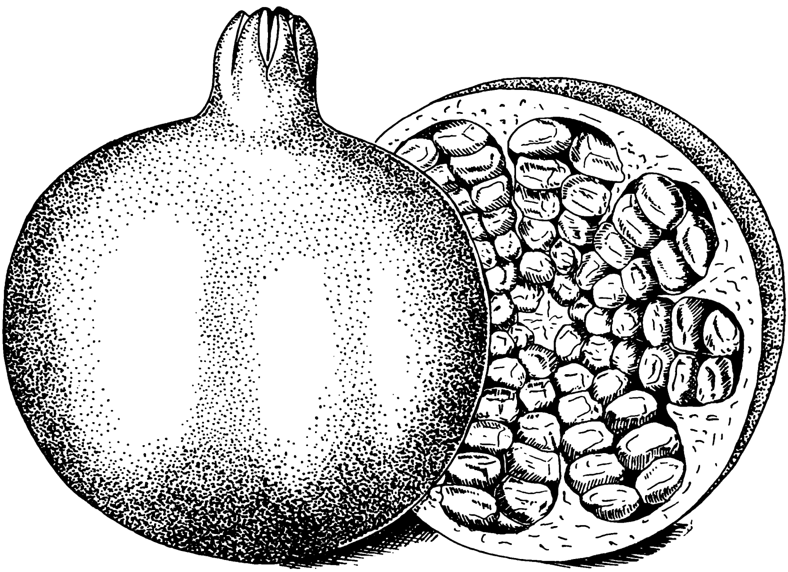


Fig. 17. Fruit and section of fruit of Bala Mursalle pomegranate

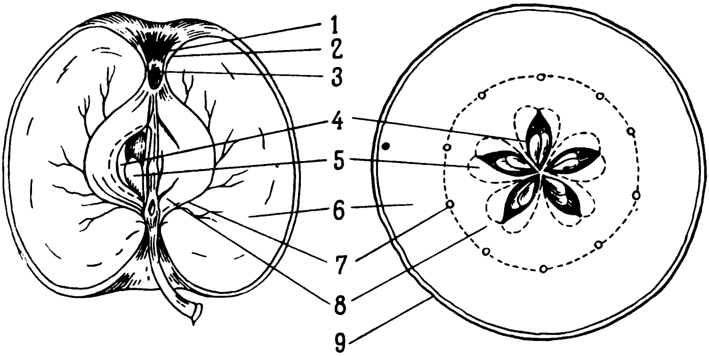


Fig. 18. Longitudinal and transverse sections of mature apple:

1—calyx lobes; *2*—stamens; *3*—styles; *4*—endocarp; *5*—seed; *6*—mesocarp; *7*—vascular bundles; *8*—pith of receptacle; *9*—exocarp

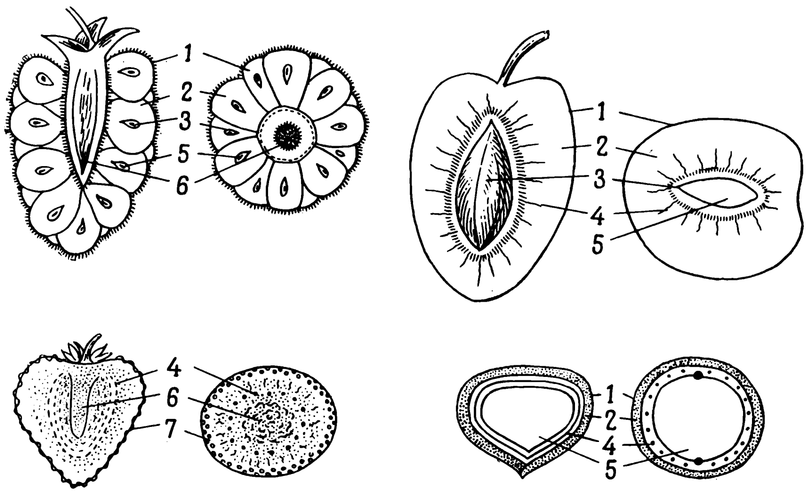


Fig. 19. Morphology and anatomy of fruits:

1—exocarp; *2*—mesocarp; *3*—endocarp; *4*—vascular bundles; *5*—seed; *6*—enlarged receptacle; *7*—drupelets

The lemon, mandarin, orange and some fruit plants have a leathery pericarp while in others it is fleshy and edible; these are sometimes referred to as berrylike fruits. A somewhat similar fruit is the pomegranate; it has a pericarp which is entirely leathery and inedible but its numerous seeds are each buried in an edible pulp (Fig. 17).

The drupe is formed from a monocarpellary or syncarpous gynaecium. Examples of drupes are sour cherry, plum, apricot, olive, bird-cherry and Cornelian cherry, the middle region of whose pericarp, the mesocarp, is soft and succulent while its inner region, the endocarp, is hard and makes what is commonly known as a "stone". Some other drupes such as almond, walnut, pistachio have a dry, edible mesocarp.

2. *The false fruits* are formed from the whole flower, including receptacle and ovary, making a composite structure (Fig. 18). Hence we may speak of receptacular pseudocarps. Examples are apple, pear, quince, rowan and hawthorn whose fruits are called *pomes*. The fruits of walnut, filbert and sweet chestnut are also considered false because they are enclosed in united bracts (Fig. 19).

3. *The aggregate fruit*, e.g., strawberry, raspberry, dewberry, is also a receptacular pseudocarp. It is developed on a common receptacle where enlarged pistils crowd together to form a composite fleshy fruit commonly referred to as a berry.

4. *The infructescence* or *inflorescent fruit*, e.g., fig and mulberry, is formed from a whole inflorescence where individual flowers are united, as distinct from an aggregate fruit, into a single structure. The individual flowers of such inflorescences can be distinguished only at the earliest stage of their development. A typical example is the *syconus* of the fig, each tiny fig drupelet corresponding to a plum "stone".

The fleshy edible part of different fruits may be composed of only one or two to three groups of tissue. The outer layer or epicarp is usually thin, consisting of one or two layers of cells. The middle region or mesocarp constitutes, e.g., in pome and stone fruits, a rather thick layer of thin-walled sack-like cells filled with edible juice at maturity stage.

The fruits of certain species, e.g., olive, have a high content of oil in the mesocarp. The flesh of pear and quince

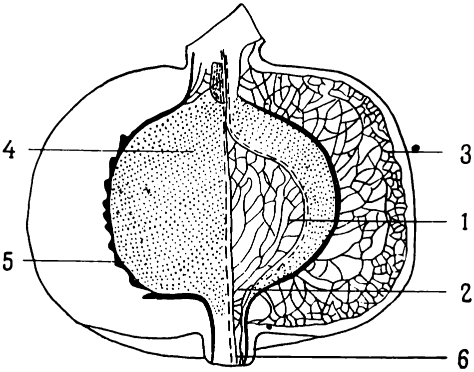


Fig. 20. Anatomy of mature apple:

1—seed; *2*—bundles supplying ovule; *3*—pit region; *4*—secondary cortical bundles; *5*—inner vascular bundle; *6*—inner vascular cylinder; (after Gourley)

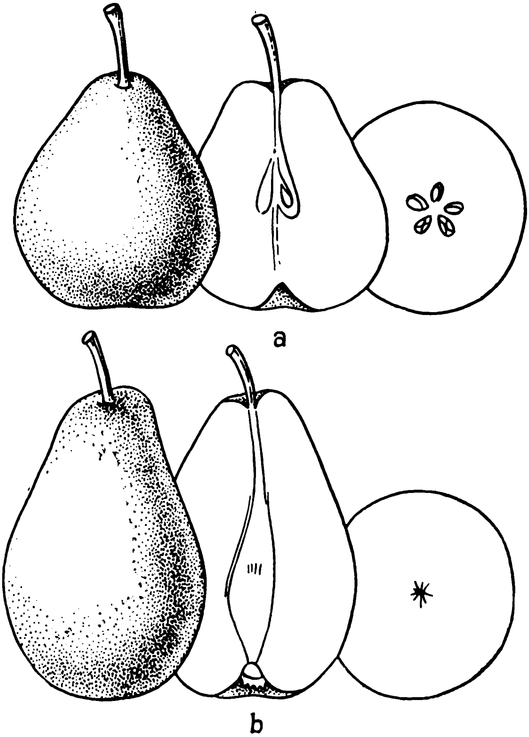


Fig. 21. Fondant du bois pears:

a—normally pollinated, entomophilous; *b*—unfertilized, parthenocarpous

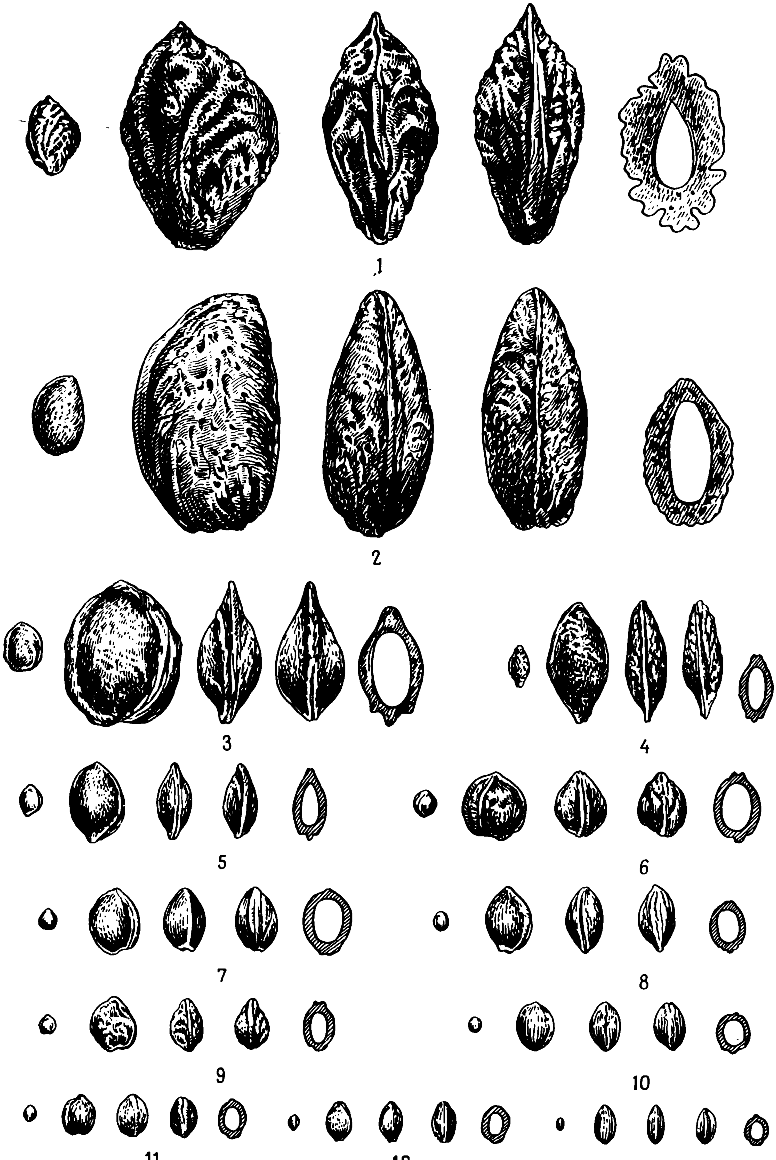


Fig. 22. Seeds of stone fruits:

1—peach; *2*—almond; *3*—apricot; *4*—common plum; *5*—Canadian plum; *6*—Ussurian plum; *7*—cultivated sweet cherry; *8*—Caucasian myrobalan plum; *9*—blackthorn; *10*—Western sand cherry; *11*—sour cherry; *12*—steppe cherry; *13*—mahaleb cherry, (after M. D. Kuznetsov)

"pomes" contains, singly or in groups, thick-walled cells known as *grit cells*. The inner portion of the pericarp which surrounds the seed is called the endocarp. Fruits rarely lack endocarp altogether while in others, e.g., sour and sweet cherry, plum and apricot, the endocarp is hard and referred to as a "stone".

In the citrus fruits the opposite occurs; their endocarp is transformed into the main edible fleshy part while the mesocarp is inedible and makes a thick leathery rind covering the fruit. All fleshy fruits are pierced by a great network of vascular tissues (Fig. 20).

Certain fruit plants such as pear, apple, persimmon, fig and mandarin may develop fruit without fertilization. Such fruits are called *parthenocarpous* or seedless. They have either no seeds or only rudimentary seeds, e.g., Fondant du bois and Curé, or big "empty", embryoless, seeds, e.g., Williams' bon Chrétien.

The parthenocarpous fruits are usually of the same size, quality and chemical composition as the fertilized fruits (Fig. 21) (V. A. Kolesnikov, 1927). Parthenocarpy can also be induced by application of certain hormones and by other methods.

The seed. To understand the biology of fruit plants the student should know seed structure and their number in fruits and be able to assess seed quality, which is most essential for the fruit grower when selecting seed material for raising rootstocks (Fig. 22).

Seed is the product of a fertilized ovule. The pome fruits have two or more ovules in each of their five chambers so that the total number of their seeds may in favourable conditions be quite large. The stone fruits only have two ovules one of which usually fails to develop so that one or rarely two seeds are produced.

A ripe seed of a fruit plant consists of a protective testa or seed coat, a mass of food-storing tissue or perisperm (containing oil and protein) and an embryo differentiated into a plumule or shoot at one end and a radicle or root at the other, the whole wedged between two cotyledons (Fig. 23). The cotyledons represent initial leaves and contain stored food necessary to start the plant on its development. It can be said that any fruit plant seed has enclosed within itself the whole plant in miniature complete with root, stem and leaves.

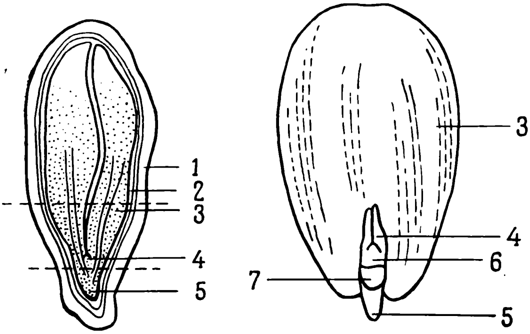


Fig. 23. Longitudinal sections of seed: apple (*left*) and almond (*right*):

1—testa; *2*—perisperm; *3*—cotyledons; *4*—plumule; *5*—radicle; *6*—hypocotyl; *7*—omphalodium (magnification high for apple seed and slight for almond seed); (after Tromcan)

As regards the number of seeds in apples C. S. Crandall (1917) established the following:

(a) cultivated varieties (82 varieties studied) averaged 8 seeds per fruit or about twice as many as the wild species, which averaged 4.2 from 45 species studied;

(b) large-fruited varieties averaged 8.3 seeds per fruit from 42 varieties studied or slightly more than the small-fruited varieties, which averaged 7.2 from 40 varieties, the difference thus being insignificant;

(c) the number of seeds in apples varied from 4 to 15 or even over 20.

Morphology and role of leaves. The role of leaves just as that of roots is varied. Leaves carry out the following important physiological functions:

(1) as the photosynthesizing organs, they produce carbohydrates as well as amino acids, proteins, vitamins, enzymes and other biologically important substances;

(2) ensure by supply of carbohydrates the growth and activity of absorbing roots;

(3) carry out transpiration and aeration in the plant.

The size of leaves varies with species, variety and their position on the plant. The leaves growing on water sprouts and maiden laterals are considerably larger than those on fruit spurs of the same tree, particularly if they are old.

Younger trees and trees enjoying better care also have larger leaves.

The condition of the whole plant depends to a great extent on leaf development and activity. The bigger the total leaf surface, the greater the speed of assimilation, i.e., the increase in dry matter per leaf surface unit per time unit. The quicker they grow and the larger they are, the more organic substances they synthesize. Good leaf development is one of the most important requirements for good tree development. One square metre of leaves produces about 6-8 grams of carbohydrates per day.

Investigations conducted in similar conditions in the Uzbek republic showed that:

(a) 15-20-year-old Rosemarine blanche and Simirenko's Reinette apples averaged 250,000 leaves, apricots 115,000, sour cherries 69,000, sweet cherries and plums each 59,000 and peaches 24,000;

(b) apricots had the biggest average leaf surface, 36.1 sq cm, and plums the smallest, 16.7 sq cm; with peach, sweet cherry, apple and pear placed in receding order between the two;

(c) assimilatory leaf surface per hectare of orchard was for apricots, sour cherries and apples from 2.2 to 6.1 hectares, sweet cherries from 0.5 to 2.6, plums from 0.6 to 1.9, pears and peaches from 0.5 to 0.9 (A. A. Rybakov, 1956).

The number of stomata on leaves varies depending on environmental conditions. The drier the soil and the surrounding air and the more sunshine the plant gets, the more stomata on the leaves and the denser the leaf venation. The higher up the branch the leaves are, the more stomata they have per surface unit. These facts are used by the fruit grower as pointers to plant condition.

CHAPTER TWO

BIOLOGICAL AND ECONOMICAL CHARACTERISTICS OF FRUIT PLANTS

Origin and Distribution of Wild-Growing Fruit Plants

Most of the numerous kinds and varieties of fruit plants now cultivated in Asia, Europe, America, Africa and Australia date back to pre-historic times. They have evolved to their present state in the course of many centuries under the influence of different climatic, soil and other ecologic conditions. Their features such as size, growth and fruiting vigour, longevity, drought-, heat- and frost-resistance, disease and insect immunity as well as certain environmental requirements have become fixed through heredity.

Since ancient times man has used fruits, berries and nuts of many wild plants for food. Most of the now existing fruit plants, both wild-growing and cultivated, owe their origin to seed and plant migration through conscious human effort as well as through the agency of animals, wind and water, to selection carried over the centuries; and to natural and, subsequently, purposeful cross-fertilization. And for a long time to come man will go on tapping the world's rich stock of wild fruit plants subjecting them to further study, improvement and utilization.

In 1926 N. I. Vavilov launched a programme designed to pinpoint the world distribution of the parent forms of all cultivated plants. He spoke in terms of localization of the initial process of form development. Summing up all the information he could then gather—from his extensive travels and agricultural literature—N. I. Vavilov has established six major world centres of plant origin. They are: (1) South-East Asia, (2) East India and the adjoining areas, (3) the Highlands of China, (4) Ethiopia, (5) the Mediterranean countries and (6) Central and South America.

The work begun by N. I. Vavilov was continued by other scientists. In 1940 N. V. Kovalyov published the results of his investigations into the origin of tree and soft fruits. He holds that the bulk of various species of fruit plants of Eurasia and North America is concentrated within an area bounded by 35° and 40° North latitude—the so called fruit belt—in the Balkans, the Caucasus, Middle and Central Asia (Kopet-Dag, Tien-Shan, etc.) and partly in North-West India, East Asia and North America.

These areas, according to N. V. Kovalyov's estimations, show a great variety of forms of 30 species of *Malus*, *Pyrus* and *Prunus* each, up to 50 species of *Amygdalus*, nearly 130 species of *Cerasus* and some 20 species of *Corylus*, as well as of peach, sweet chestnut, apricot and walnut.

In view of different climatic conditions and the immense variety of plant genera, species and forms, N. V. Kovalyov divided the fruit belt into six major areas as follows:

(1) the Mediterranean area with its numerous provinces;

(2) the South-West-Asian area which includes all of Asia Minor except its western area, the Caucasus, central Asia, Iran, Afghanistan and North-West India;

(3) the East-Asian area which includes central and east China, Manchuria, the Highlands of the Far East, Japan, Korea and North Taiwan;

(4) the North-American area which includes the central and eastern states;

(5) the South-East-American area which includes the south-eastern states, except Florida;

(6) the Mexican-Californian area which also includes the states of Nevada, New Mexico and Texas.

For wealth of temperate-climate pome fruits, stone fruits, berries and nuts the Soviet Union occupies first place in the world, while the Chinese People's Republic ranks first for the subtropical fruit plants. In the opinion of Soviet Academician P. M. Zhukovsky (1950), these two great countries had served in the past and would serve even more in the future as the main source of plant material for temperate and subtropical fruit growing.

As to the wild-growing fruit plants the resources of the U.S.S.R. are indeed colossal and so far insufficiently used for fruit breeding. The greatest variety of wild fruit plant species among the different areas of the country is

displayed by the Caucasus, with Central Asia and the Far East as runners-up. Almost all fruit plants found in the country grow in the forests of the Caucasus, except citrus and some subtropical fruits. Over 80 species of fruit trees and shrubs are found here, including the sweet chestnut on a territory of some 70,000 hectares and the beech bearing edible nuts on a territory of about 800,000 hectares.

Over 70 varieties of fruit plants grow in the Soviet republics of Central Asia, of which the walnut occupies about 100,000 hectares and the pistachio about 200,000 hectares. Growing on the vast expanses of Siberia are berries, *M. Pallasiana*, mountain ash, sea buckthorn and cedar nuts with an area of possible harvesting of 550,000 hectares. The Far East has 74 different species of fruit plants, mostly of apple, Ussurian pear, plum, apricot, actinidia and Manchurian walnut.

The European part of the U.S.S.R. abounds in wild-growing fruit plants: Cornelian cherry and hazel down in the Crimea, apples and pears in Kiev, Kursk and Voronezh regions; berries in Karelia and Leningrad Region; the ground cherry in the Volga area, etc.

According to the All-Union Plant Breeding Institute data, wild-growing fruit plants in the U.S.S.R. occupy a territory of about 7 million hectares.

The Soviet Union as well as some other countries, especially the U.S.A. and Canada, owe a considerable part of their range of cultivated pome fruits, stone fruits, nuts and berries to the rich flora of the U.S.S.R.

Wild-growing fruit plants have a great economic importance. They provide extra hundreds of thousands tons of food of high nutritional value, as well as a huge seed stock for windbreaks, for landscape gardening, highway planting, etc.; they are also used for breeding purposes and as rootstocks. It must be said, however, that the world's wild plants, and this is also true for the U.S.S.R., are still finding inadequate use as parent stock for new varieties and as a source of extra food.

Fruit, nut and berry plants are divided into botanical families, genera and species. In Soviet horticulture they are usually classified as follows: 1) pome fruits, 2) stone fruits, 3) nuts, 4) subtropical fruits, 5) citrus fruits, 6) berries or soft fruits.

Pome Fruits

The apple is the most widely grown fruit plant in the U.S.S.R., occupying a total area of about one million hectares (32.9 per cent of orchard territory). The trees reach a height of 6-10 m and more (up to 14-15 m in Uzbekistan and Moldavia). Owing to a big varietal range many sorts possess valuable biological and economical features, including winter hardiness. Apples can be successfully grown in the central and northern as well as in the southern fruit-growing zones. According to ripening time, apples are divided into summer, autumn and winter varieties.

The U.S.S.R. register of standard fruit varieties includes about 300 apple varieties. These can be divided as follows:

(a) traditional varieties: Antonovka, Anis, Borovinka, Grushovka Moskovskaya, Sary Sinap, Candil Sinap, Sary Tursh, Kekhura, Simirenko's Reinette, Apport Aleksandriisky, etc.;

(b) varieties originated by I. V. Michurin and other breeders: Pippin Shafranny, Bellefleur-Kitaika, Slavyanka, Chernenko's Pippin, Mleyevskaya Krasavitsa, Petrov's Desertnoye, etc.;

(c) imported varieties: Reinette de Champagne, Rosemarine blanche, Jonathan, Delicious, London Pippin, Wealthy, Melba, etc.

Fruits of many varieties are transportable, late-keeping (so that fresh fruit is obtainable the year round), highly nutritional and very pleasant to eat fresh and processed.

Depending on variety and rootstock, apple trees begin to bear from the age of 4-15 years. Average yields are 5-20 t per hectare and, in better conditions, up to 50 t (the Crimea, Voronezh Region), 80 t (Skreblovo State Farm, Leningrad Region), and even 100 t (Kibrai State Farm near Tashkent). Under good natural conditions and adequate management the yield from an apple tree may be as high as 0.5 t (Anis Polosaty), 0.7 t (Bellefleur-Kitaika), 1 t (Antonovka Obyknovennaya), 1.6 t (Rosemarine blanche), and 2 t (Sary Sinap).

Depending on variety, rootstock, natural conditions and cultural practices, apple trees have an average longevity of 25 to 50 years, which in optimal conditions may

be as high as 70 to 100 years, e.g., Anis in the central zone and Sary Sinap in the southern zone.

The main areas of commercial apple growing are: the Russian Federation, particularly Middle and Lower Volga region, Voronezh, Kursk, Tambov and Ryazan regions, Northern Caucasus, Urals and Siberia; the Byelorussian Republic, the Ukrainian Republic, particularly Crimean and Kiev regions and Vinnitsa-Dniester areas; Central Asia, particularly Tashkent and Alma-Ata areas; the Moldavian Republic.

All of the apples belong to one genus, *Malus*, a member of the subfamily *Pomoideae* of the numerous family *Rosaceae*. It comprises over 30 species and some 60 subspecies, all of them indigenous in the Northern Hemisphere—in Middle and Central Asia, China and North America.

Some botanists prefer to unite the apple and pear in the one genus *Pyrus*, as does L. H. Bailey in "The Standard Cyclopedia of Horticulture", on the grounds that the evident botanical distinctions between the two groups are rather insignificant. Still others prefer to keep them distinct largely due to the reason that the apple and the pear seem to have a different phylogenetic origin.

All the world's cultivated varieties of apples — and they number over ten thousand—were evolved from a few wild-growing species. The most important of these are the following:

M. sylvestris Mill. A tall tree (up to 15 m and more) in southern areas and a small tree or bush in northern areas. The head is round, with numerous small branches not infrequently spiny. There are usually no root suckers. The root system is deep and powerful. Root fibre is moderate, less pronounced than in *M. Pallasiana* and the Chinese apple. Shoots, leaves and ovaries in the early stages of development are slightly pubescent and quite glabrous in the later stages. Leaves are usually broad-ovate or almost round, with serrate margins. Flowers are in clusters with pink-coloured petals.

Fruits are usually round-ovate, averaging 2-2.5 cm across, greenish-yellow in colour, sometimes blushed, subacid, astringent; they are used for preserving and for seed in stock-raising. This species grows on all the territory of the European part of the U.S.S.R., particularly in Kursk, Voronezh and Kharkov regions. It has many varie-

ties that differ widely in size of tree, longevity, yield and fruit size and quality.

It is considered to be one of the principal parent forms of the numerous apple varieties now in cultivation in all countries.

M. pumila Mill. is closely related to the above-mentioned wild apple tree, differing from it by smaller tree size and considerable pubescence on shoots, buds, leaves and ovaries. More often it is a small tree or bush. Leaves are ovate or oval, serrate-crenate. As a southerner, it is less winter-resistant than the above. It produces a profusion of shoots and root suckers and can be propagated by cuttings and suckers. Its root system is less deep than that of *M. sylvestris.* It grows in the Caucasus, the Crimea and Central Asia.

This species is commonly held to be the parent form of many cultivated varieties. Its varieties are the Doucin apple, the Paradise apple and Niedzwetzky apple classed by some botanists as separate species.

The Doucin apple (*M. praecox Pall*). A small shrub-like tree, up to 5 or 6 m high. Very branchy; young branches have a dark, almost black colouring with white lenticels and slender buds; is easily propagated by layers, cuttings and root suckers. It matures early and bears sweet fruit in summer. The Doucin apple is widely used in the south as rootstock for semi-dwarf forms.

The Paradise apple (*M. paradisiaca* Schn). A bush or a small tree reaching two metres in height; bears earlier after planting, has a shorter life and produces more root suckers than the Doucin apple. The root system reaches as deep as 5 m in the south but fibre lies close to the surface; roots are brittle. Young shoots are green at first, then brown with a red tinge; wood is yellow, is easily propagated by layers, suckers and cuttings. The Paradise apple is much used as rootstock for dwarf and tub forms. It has been established that Armenia's dwarf apple, Marga Khandsor, is identical with the Paradise apple.

R. G. Hatton (1919, 1939) in England was the first to gather a large collection of dwarf *M. paradisiaca* Schn. and *M. praecox* Pall. rootstocks and make a study of them. He established 16 types of clonal rootstocks similar in their morphological and biological features and gave each a number under which they are known and propagated to this day.

Recently new clonal apple rootstocks, known as the Malling-Merton rootstocks, have been bred by the East Malling Research Station and the John Innes Horticultural Institution in England. At present the MM rootstocks (101-105) are undergoing trials in the U.S.S.R.

The Niedzwetzky apple (*M. Niedzwetzkyana* Dick). A large tree native to Central Asia. Differs from the above varieties by the reddish to red pigment in wood, leaves, flowers and fruits. This feature was used by I. V. Michurin to obtain red-fleshed varieties such as Bellefleur Record and Komsomolets. It is believed that a number of red-fleshed cultivated varieties, e.g., Krasnii Calville, have originated from the Niedzwetzky apple.

M. dasyphylla Borkh. is an intermediate form between *M. sylvestris* and *M. pumila*. The tree is long-lived (to 80-100 years), drought-resistant but not winter-hardy, and reaches a height of 6-10 m. Shoots, buds and leaves beneath are slightly pubescent. Fruits vary in shape, size and colour, more often are white or yellow, sometimes fairly large, reaching 20-40 g. This species grows in the south of the European part of the U.S.S.R., in the Caucasus, Central Asia, particularly on the spurs of Transili Alatau (commonly known there as the Alma-Ata apple), and in Western Europe. Makes a good rootstock for apples in the southern regions.

The Chinese apple (*M. prunifolia* Borkh.). An upright-spreading, densely-branched tree, up to 10 m high. Leaves are glabrous, glossy, elongated, resembling the leaves of a plum tree (hence the name, *prunifolia*). Flowers are white whereas most other species have pinkish to pink flowers; the calyx is persistent. Fruits of many of its varieties are small but still bigger than those of *M. Pallasiana*, some of the varieties bearing fruit weighing as much as 40 g. It has a powerful root system, though less deep than that of *M. sylvestris*, very branched and winter-resistant.

Some of the varieties of *M. prunifolia*, e.g., Kitaika Saninskaya, are cultivated in the central zone of the U.S.S.R. It is extremely hardy and drought-resistant. Some researchers consider it to be a hybrid of *M. Pallasiana* and a cultivated apple. According to A. Rehder, it is a natural species. I. V. Michurin attached great value to it. He used a large-fruited semi-cultural form of *M. prunifolia* for hybridization, e.g., in breeding his Pippin

Shafranny, and recommended it as a hardy stock for use in the central and Volga areas. Its repute of a good hardy rootstock has since been established.

The Siberian crab apple (*M. baccata* Borkh.). A large tree, up to 10 m high, or a round-headed compact bush. Shoots are usually glabrous with a characteristic reddish-brown colouring and covered with sharp-ovate buds. Leaves are ovate to ovate-lanceolate, glabrous and glossy; flowers are white. Fruits are very small, 0.5 to 1 cm across, reddish or yellow, with a falling calyx. The species is cultivated in the U.S.S.R., Japan and China and is not known in the wild; it is quite hardy.

M. Pallasiana Juz. A round-headed tree. Shoots are ash-grey and glabrous with the exception of growing tips. Fruits are small and round averaging 1 cm across, long-stemmed, yellow with a red tinge, subacid, very astringent. It is very hardy. The tree is native to areas round Lake Baikal and in Buryatia. Ranetka Purpurovaya and Yantarka Altaiskaya are examples of the cultivated varieties related to the species.

The wild-growing species described were used as original forms in the development of the European apples, while most pomological apples of East Asia and America owe their origin to the Chinese species, *M. Halliana* Koehne, *M. hupehensis* Rehd, and *M. spectabilis* Borkh.; to the Japanese species, *M. floribunda* Sieb., *M. Toringo* Sieb., *M. Zumi* Rehd. and *M. Ringo* Carr., and to the North-American species, *M. coronaria* Mill., *M. fusca* C. K. Schneid.

The pear occupies the fifth place in orchard coverage (6.2 per cent). Its most valuable character—high-quality fruit—is somewhat offset by certain unfavourable ones. Compared with the apple, the pear is lacking in hardiness, requires altogether warmer temperatures and is more exacting to soil and climatic conditions. This limits its wide distribution, e.g., it accounts for no more than two per cent of orchard territory in the northern zone of the U.S.S.R. But though it is grown mostly in the southern zone recent successes in pear-breeding are opening the way for it to the north of the country.

The U.S.S.R. Register of Standard Fruit Varieties lists about 130 varieties of pear, including home varieties: Bessemyanka, Tonkovetka, Ilyinka, Gliva Ukrainskaya, Khachatury; Michurin's varieties: Michurin Beurré Zim-

naya, Beurré Oktyabrya; imported varieties—Beurré Bosc, Williams' Bon Chrétien, Beurré d'Hardenpont, Curé, Fondant du bois, Clapp's Favourite.

According to ripening time, the pears are divided into summer, autumn and winter varieties. That means that fresh fruit can be had almost the year round. The fruit is rich in nutritional substances, excellent when eaten fresh and good when processed. But they do not stand storage and shipment as well as the apples.

Depending on variety, rootstock, natural conditions and cultural practice the pear trees start bearing from the age of 4 to 10 years; tree longevity is 25 to 50 and more years; yields average 12 to 18 t per hectare (Kaunchi State Farm), some varieties yielding as much as 1.4 t (Uzbekistan) per tree and up to 60 t per hectare (Krasny State Farm in the Crimea).

The main areas of commercial pear-growing are the Uzbek S.S.R. (areas round Tashkent and Samarkand), the Georgian S.S.R. (Gori district), the Northern Caucasus, Crimean and other regions of the Ukrainian S.S.R., and the Moldavian and Byelorussian Republics.

The genus of the pear, *Pyrus*, belongs to the subfamily *Pomoideae* of the family *Rosaceae*. There are about 60 species, mostly native to Europe and Asia, out of which 18 are in the U.S.S.R. All the pear varieties, and there are several thousand of them, have come from a limited number of wild-growing species. The following are the main of them.

The common pear (*P. communis* L.). Usually a large vigorous tree, up to 20-25 m high, sometimes a bush; upright-spreading, with long main branches, moderate number of secondary and tertiary branches and a big number of short vegetative and fruiting growths. The root system is deep, particularly in the south, compact, less fibrous than that of the apple tree.

Shoots, buds and leaves are glabrous, sometimes pubescent. Leaves are mostly oblong-ovate, denticulate. Flowers are in umbel-like clusters of 6 to 9 or more, large, with white petals. Fruits are elongated or rounded, variable in size, reaching 3-4 cm in length, yellow or green, hard, astringent; they are processed and seed is used to grow seedlings on which orchard varieties are most commonly budded.

The common pear grows in the wild in Europe and Asia. In the U.S.S.R. it is widespread in the Caucasus,

the Ukraine, the Russian Federation (Kursk and Voronezh Regions), in Turkmenia and Kazakhstan. There are many races greatly differing in size of tree, longevity, winter hardiness and other morphological and biological characters. The common pear is considered to be one of the principal parent forms of the numerous orchard varieties.

The snow pear (*P. nivalis* Jacq.). A medium-sized spreading tree, sometimes a bush-like tree, or a bush. Shoots, buds, leaves beneath, inflorescences and ovaries are covered with white, felt-like down, which probably explains its name. Leaves are elliptic to oval, entire or minutely crenulate. Fruits are up to 5 cm in diameter, yellow or green, subacid, very astringent; are used preserved and for the making of perry or pear cider in France and England. It is less hardy than the common pear but drought-resistant, which should commend it for stock in droughty areas. It is native to Central Asia; it grows wild in Austria, France and the Caucasus.

P. eleagrifolia Pall. is genetically related to the snow pear and shows great resemblance to it in pubescence and some other characters, but is classed as a separate species. It is a tree of 10-12 m in height, sometimes a bush, round-headed and spiny. Extremely frost- and drought-resistant, it is used for stock in the south. It grows wild in the Crimea, Asia Minor, and in the east of the Balkans.

The Ussurian pear (*P. ussuriensis* Maxim.). A dense upright-spreading spiny tree, up to 10-15 m high. Shoots are glabrous; leaves are broad, often nearly orbicular, strongly setose-serrate; flowers are 3-4 cm across, with white petals; fruits are 3 to 4 cm across, elongated or rounded, greenish-yellow, with a persistent calyx, of poor quality.

The Ussurian pear is the hardiest species of pear known. I. V. Michurin, A. M. Lukashyov and some other Soviet breeders have made extensive use of it for producing numerous frost-resistant sorts, e.g., Michurin Beurré Zimnaya and Tyoma. A native to the Far East, it is used for stock in areas with severe climates such as the Urals, Siberia and the Soviet Far East.

The sand pear (*P. serotina* Rehd.). A tree reaching 15 m in height, with unarmed branches and drooping shoots. Leaves are large, ovate-oblong and sharply setose-serrate. Flowers are large; fruits are subglobose, hard, with a calyx falling at maturity. The species is native to central and

western China. In the U.S.A. cross-breeding with it has yielded several varieties, e.g., Kaifer's Seedling which is now a standard pear in the Kuban area (Russian Federation). Several varieties based on the sand pear have been bred in Primorsky Territory (Soviet Far East). They proved to be fungus-resistant and bear fruit with good keeping qualities.

The quince. Up till very recent times the quince has been poorly represented in the orchards of the U.S.S.R., occupying only 0.6 per cent of the orchard territory. Due to the development of canning industry work has now begun on planting big quince orchards. It is a small tree with a vertical root system, reaching 4 m deep in the Crimea. It comes early into bearing, is a late-bloomer and requires warmth and moisture so that the best crops are obtained on irrigated land. It is not fastidious as to soils but does best on somewhat heavier soils.

The quince starts bearing after 4-5 years and is fairly productive, yielding up to 20-50 t per hectare. It does not stop bearing until the age of 30 to 45 or more years. The large (0.5 kg and more) late-ripening fruits have good shipping and keeping qualities; they are hardly edible when fresh but are excellent for canning.

The varietal range of the quince is not extensive. The popular varieties are the following: Akhmed Jum, Golotlinskaya Yablokovidnaya, Skorospelka, Orange, Anzherskaya, Portugalskaya. The quince is grown in Central Asia, the Crimea, the Caucasus (Daghestan, Azerbaijan) and the Lower Volga area (Astrakhan and Volgograd Regions).

The genus of the quince, *Cydonia*, belongs to the subfamily *Pomoideae* of the family *Rosaceae*. The genus consists of a single species from which all the orchard varieties took their origin.

The common quince (*C. oblonga* Mill.). A small dense round-headed tree or a large shrub, up to 5 m high. It gives numerous root suckers. Shoots and buds are thickly covered with hairs. Leaves are large, broad ovate, hairy beneath. Flowers are rather large, single, white or light pink, terminal on short leafy branchlets. Fruits are large, weighing up to 80-100 g, yellow, downy, inedible when fresh but good when preserved. It is usually propagated by cuttings of one- to four-year old wood and by layers. It is used as rootstock for budding or grafting the pear. The common quince grows

wild in Central Asia, Transcaucasia and the Caucasus. Its relative, the Japanese quince, a member of a different genus, *Chaenomeles*, is a common sight in parks and orchards starting from the south of the country and up to the Moscow Region. Grown as an ornamental, its fruits can be used for making preserves.

The rowan or mountain ash. It is a tree fruit little cultivated in the U.S.S.R. The root system is of a surface type and spreads far, up to 6 m on either side at the age of 35 years. It is exacting as to light, very little as to warmth and soil, and is very hardy. The fruit is of variable shape and size, and edible when fresh and when processed. Trees begin bearing when 7-8 years old and live to the age of 60-70.

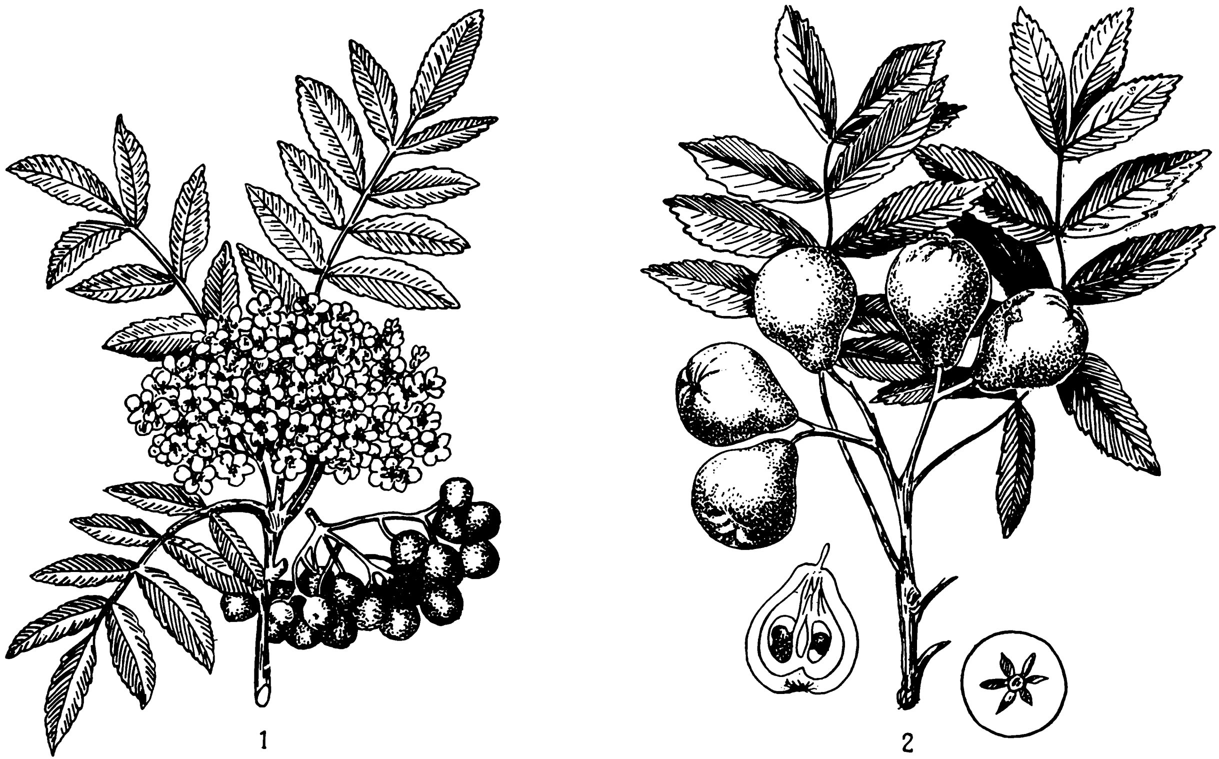
The popular varieties are: (a) local, e.g., Kubovaya, Zheltaya and (b) Michurin's, e.g., Likyornaya, Burka, Granatnaya, Michurinskaya Desertnaya.

The genus of the mountain ash, *Sorbus*, belongs to the subfamily *Pomoideae* of the family *Rosaceae*. There is a total of about 80 species of the mountain ash in the world, including over 30 on the territory of the U.S.S.R.; there are also many hybrid forms.

The mountain ash is found all over the world, but mostly in the north or in the mountainous regions of the south. Quite a few of the species are very hardy such as Polyarnaya, Sibirskaya, Buzinolistnaya, some of these even growing inside the Arctic Circle. So far it has been inadequately used for hybrid work and as a windbreak and shelter-belt tree.

The rown or *European mountain ash* (*S. Aucuparia* L.). A tree, 5-15 m high, with a smooth grey-coloured trunk and rather thick and sturdy branches. Leaves are alternate, odd-pinnate; leaflets are oblong-lanceolate, serrate. Inflorescences are large, tomentose corymbs; flowers have a strong smell, petals are white. Fruits are globose, small, bright red, bitter and astringent, and are usually used for making preserves, while the seed is used for growing stocks (Fig. 24).

The mountain ash grows wild all over the U.S.S.R., but mostly in the northern zone of the European part, in Siberia and also in the Caucasus. The tree has many varieties, including sweet-fruited ones: Nevezhinskaya and Moravskaya.



1

2

Fig. 24. 1 — European mountain ash; *2* — Service tree

The service tree (*S. domestica* L.). An upright-spreading thick-trunked tree, up to 9-20 m high. Leaves are compound, odd-pinnate, with 11-21 leaflets. Flowers are in white-petalled corymbs. Fruits are large (20-25 g), apple- or pear-shaped, green or brownish. Flesh is juicy, mildly subacid, astringent, aromatic, pleasant. The service tree is native to South Europe, North Africa and West Asia. Many of its forms grow in the Crimea where it has been domesticated since old as a fruit plant. It is not hardy.

The black chokeberry (*Aronia melanocarpa* Heynh.) belongs to another genus, *Aronia*, related to *Sorbus*. It is a low shrub, up to 1.5-2.5 m high, with slender branches. Leaves are simple, oval to obovate, abruptly acuminate or obtuse; fruits are rounded, 1.5-1.7 cm across, with tough skin, shining black; juice is dark-ruby, mildly subacid, very sweet.

The black chokeberry is native to North America; in the U.S.S.R. it is a standard variety in Altai Territory, Sverdlovsk and Leningrad Regions. I. V. Michurin strongly recommended it for use as a windbreak plant.

The medlar. It is not grown extensively. It is a spreading tree of moderate size, 4-5 m in height. It requires warmth and is not hardy. The medlar grafted on hawthorn does well on light and dry soils, and when grafted on quince, on dense and moist soils. Fruits are about 3 cm across and become edible when stored to lose astringency, the ripening process being known as bletting. They are also used to make preserves and liqueurs; they average 10 per cent sugar, 0.5 per cent acid and 0.5 per cent fat.

The Ispolinskaya, Skorospelaya and Korolevskaya are the leading varieties. The medlar is cultivated in the Caucasus and southern Ukraine.

The medlar belongs to the genus *Mespilus*, a member of the subfamily *Pomoideae* of the family *Rosaceae* and is represented by a single species, *M. germanica* L. A small spreading tree or shrub, with brownish shoots. Leaves are elongated-oblong, serrate or entire, pubescent beneath; flowers are white or pinkish. Fruits are 1.5-2.5 cm across, round-oblate, edible when touched by frost and fully ripe. It grows in the wild in the Caucasus, Transcaucasia, the Crimea, as well as in Iran, Asia Minor, Greece, and the Balkans.

The hawthorn. The genus of the hawthorn, *Crataegus*, belongs to the subfamily *Pomoideae* of the family *Rosaceae*.

The genus includes 100 species, according to J. C. Willis; 39 species are recognized in the U.S.S.R. Some of the species yield edible fruit of a peculiar taste, others can be used as ornamentals, in windbreaks and, in some cases, for stock. Most hawthorns grow wild in North America. The following species are grown for their fruit.

The silver hawthorn (*Cr. orientalis* Pall.). A shrub or small tree, up to 3-5 m high, with spreading spiny branches. Fruits are 2 cm across, subacid, pleasant, have 4 per cent sugar while their seeds contain up to 38 per cent oil. It grows in the wild on dry slopes in Transcaucasia and the Crimea.

Cr. pontica G.Koch. A round-headed tree, 7-8 m in height. Fruits are yellow, 3 cm across, aromatic and pleasant, can be also preserved. It grows in the wild in Transcaucasia and Central Asia where it is cultivated in the home yards.

The service berry or June berry (U. S.). The genus of the service berry, *Amelanchier*, belongs to the subfamily *Pomoideae* of the family *Rosaceae*. Twenty four species are known in North America and one in the U.S.S.R.

The service berry (*A. rotundifolia* Dum.-Cours.). A shrub, up to 2 m high. Fruits are the size of peas, juicy, edible, containing up to 10 per cent sugar and 0.5 per cent acid; are used for drying and for making juice, stewed fruit and preserves. It grows wild in the Caucasus and the Crimea.

Several species of the service berry make good stock for dwarfing pears and many others are grown as ornamentals.

The subfamily *Pomoideae* of the family *Rosaceae* also includes the genus of the cotoneaster, *Cotoneaster*, with several species grown as ornamental shrubs, and the genus of the wild rose, *Rosa*, whose species are cultivated for their edible vitamin-rich fruits.

Stone Fruits

The sour cherry takes second place after the apple and first among the stone fruits, occupying 27.4 per cent of Soviet orchard territory. It almost equals the apple in winter-hardiness and can consequently be cultivated further to the north than, for instance, the pear or the plum. However its fruit buds are sometimes killed by frost in the nonchernozem zone.

The sour cherry varieties, and there are about 80 of them in the Register of Standard Varieties, are grouped into the shrub type, usually with several stems (up to 2 m in height) and the tree type, with one stem (5-7 m in height). The first group of cherries is capable of producing root suckers, which are used for propagation. Their fruit is dark-red, almost black in colour, and with dark-coloured juice. These varieties are called the *Morellos* or *Griottes*, e.g., Vladimirskaya, Lyubskaya, Lotovaya.

The tree-type cherries are light-coloured with colourless juice and are less sour than the *Morellos*. They are called the *Amorelles*, e.g., Amorelle Rozovaya, Sklyanka, Shpanka Kurskaya.

These two groups are also distinguished by certain differences in fruiting and vegetative growth.

Besides the local varieties mentioned the Register of Standard Varieties includes sorts developed by I. V. Michurin and other Soviet plant-breeders: Plodorodnaya Michurina, Shirpotreb Chernaya, Krasa Severa, Zhukovskaya, etc., and imported varieties: Podbelskaya, Griotte d'Ostheim, etc.

The sour cherry starts to bear when 3-5 years old, its longevity being 20-30 years. The per tree yields reach as much as 30 kg, while some varieties, e.g., Lyubskaya, may yield up to 80 kg. The cherries contain 7.3-17.5 per cent sugar and 0.8-2.7 per cent acid, and are extensively used fresh and processed.

The northernmost boundary of the spread of the sour cherry connects the cities of Leningrad, Vologda, Kirov and Perm. It is particularly prominent in Moscow and adjacent regions, in the Volga area and the Ukraine.

The sweet cherry is a valuable fruit plant still poorly represented in the U.S.S.R. (2.1 per cent). It is a tree, often quite large, reaching 10-15 m, of tall erect growth. The sweet cherry is somewhat fastidious as to soils and lacks in hardiness to both heat and cold. It is long-lived (50-70 years and more) and starts to bear within 3-7 years after planting. It yields heavily, e.g., 200 and even 300 kg per tree in Moldavia. The round-ovate fruits are 1.5 cm across, of yellow, pink, red, or black colour, with colourless or dark-red juice, of sweet or sour-sweet taste. The fruits contain 5.8-17 per cent sugar and 0.3-1.1 per cent acid, and are used fresh and processed.

Two groups of sweet cherries are recognized, the distinguishing characters being soft or firm flesh: (1) the *Bigarreaus*, the varieties with firm crisp flesh of the fruits, such as Emperor Francis and (2) the *Geans*, the varieties with soft tender flesh, such as Rannyaya Marka and Aprelka.

A total of 75 sweet cherries are listed in the Register of Standard Varieties, of which Aprelka, Krasnodarskaya Rannaya, Krasa Kubani, Moldavskaya Chernaya are local varieties and Bigarreau Napoleon, Knight's Early Black, Emperor Francis, May Duke, Yellow Drogana and Elton are imported ones. The varieties of sweet cherries are further divided into early- (3-5 yeaıs) and late-bearing (7 years), as well as early-, midseason- and late-flowering varieties.

The sweet cherry is grown on a commercial scale mostly in the southern zone of the U.S.S.R., in the Ukraine (Crimean Zaporozhye, Melitopol and Odessa Regions), in Moldavia (Dniester Region); also in Daghestan and Northern Caucasus. In recent years, due to work done by I. V. Michurin and other plant-breeders, the sweet cherry has been introduced in Byelorussia and in Leningrad Region.

The sour and sweet cherries belong to the same genus, *Cerasus*, a member of the family *Rosaceae*, subfamily *Prunoideae*. The genus comprises about 150 species growing mostly in East Asia, of which 76 are in China alone. A total of 21 species has been described in the U.S.S.R.

A most interesting distinguishing feature of the numerous representatives of this genus as compared to the other stone fruits is the structure of their reproductive organs and the fruits developing from them, viz., both sweet and sour cherries have much longer flower pedicels and smaller fruits and stones (which are not corrugated or pitted) than the plums, apricots and, especially, the peaches.

The following few species of the sour and sweet cherry have an economic interest.

The sour or *Morello cherry* (*Cer. vulgaris* Mill.). A round-headed tree, 6-7 m in height, or a shrub, with vigorous root sucker growth. Shoots are glabrous, reddish-brown at maturity. Flowers are in small clusters of 2-4; fruits are roundish or depressed-globular, light-red, clingstone, subacid, pleasant.

This species is considered to have its origin in a natural cross between the ground cherry and a sweet cherry. All its numerous forms are distinguished by winter-hardiness,

early-maturing, vigorous shoot growth and a relatively short life of small fruiting branches and even main branches.

The wild form is not known, but the run-wild species is very common in the European part of the U.S.S.R., in the Caucasus and Transcaucasia. It has given origin to many local varieties, e.g., Vladimirskaya and Lyubskaya.

The ground or *dwarf cherry* (*Cer. fruticosa* Pall.). A small bush sometimes reaching 1-1.5 m in height, spreading, dense, suckering profusely from the root. Shoots are slender, whip-like, glabrous; leaves, as distinct from the sour cherry, are more lanceolate and small. Flowers, 3-4, are in nearly or quite sessile umbels. Fruits vary in size (8-15 mm long), in shape (oval to globose), colour (light-pink to dark-red, almost black) and taste (sour, sometimes astringent). A characteristic feature of the species is a ridged ventral suture of the stone. It is also distinguished by great winter-hardiness, drought-resistance, early-mature and high yields. As compared to all the other species, it has a shorter growing season and an earlier leaf shedding.

Many types and forms of this race grow in the wild on south- and east-exposed slopes in the European part of the U.S.S.R., especially in the Volga area and the Urals; also in Northern Caucasus, West Siberia and Kazakhstan. The species gave origin to many cultivated varieties. I. V. Michurin used it for hybridization with established varieties to originate new varieties such as Plodorodnaya Michurina, Ideal, Polyovka.

The Western sand or *Rocky Mountain cherry* (*Cer. Besseyi* Lunell.). A small spreading shrub, 1-2.5 m in height, prostrate at the base when old. Shoots are erect, slender, with small and thick, usually elliptic leaves. Flowers are small, white, in 2- to 5-flowered sessile umbels. Fruits vary in size (up to 1.5 cm across), shape (mostly ovate) and colour (red to black); flesh is juicy and generally sweet, and the cherries can be used in jam- and wine-making and for pies. The species is winter-hardy and very productive.

The species grows wild in North America on sandy saline soils and is cultivated in the U.S.S.R., particularly in Altai and Krasnoyarsk Territories. It can be used to advantage in hybridization and makes a good stock for plums, apricots and peaches.

The tomentose cherry (*Cer. tomentosa* Thunb.). A small tree-like bush, 1-2.5 m in height, with slender branches

and rugose leaves densely tomentose beneath. Flowers are white; fruits are round, currant-red in colour, up to 1.3 cm in diameter, with flesh that is spicy and insipid in taste. The species is winter-hardy and very productive.

The tomentose cherry grows in the wild in Central Asia from where it has spread to the Soviet Far East. By seedling-selection I. V. Michurin obtained from it a new variety, Ando.

The Mahaleb cherry (*Cer. Mahaleb* Mill.). A bush or a tree, 4-7 m in height, sometimes even 10-12 m, with a dense, round head and numerous slender branches; produces no root suckers. Leaves are round-ovate to orbicular; flowers are in small terminal umbels of 5-7; fruits are very small, almost black, not edible. The species is not winter-hardy.

The Mahaleb cherry grows in the wild in the Crimea, the Caucasus, Transcaucasia, Asia Minor, Turkmenia and Iran. It can be used for cherry-tree stocks to be grown on dry gravelly, or stony soils.

The sweet cherry or *Mazzard* (*Cer. avium* Moench.). A tall vigorous tree, sometimes 25-35 m in height, upright-spreading; the young trees with a strong central leader, few main branches but a great profusion of short fruiting growths. Leaves are large (up to 16 cm in length), oblong-ovate, coarsely and doubly serrate, glossy. Flowers are large, white or pink, in dense clusters. Fruits are globular or ovate, up to 1.5 cm across, yellow, red or black, juicy and sweet; are used fresh and processed; the seeds go to grow seedlings. The trees are long-lived (up to 80 years and more) and very productive.

The sweet cherry grows in the wild in the Caucasus, the Ukraine and Moldavia. It served as the principal parent form for all the cultivated varieties of the sweet cherry.

The bird cherry (genus *Padus*, species *P. racemosa* Gilib., family *Rosaceae*). A tree, 3-10 m in height, or a dense spreading bush. The bark on the trunk and branches is smooth and dark-coloured. Leaves are large, elongated. Flowers are white, fragrant, in racemes. Fruits are small, round, black, tart and sweet; contain up to 5 per cent sugar and are used both fresh and preserved. It is an early bloomer.

Native to Sakhalin and the south of the Kurille Islands the bird cherry grows all over the U.S.S.R. Another species of the genus *Padus*, the choke cherry (*P. virginiana* L.), is native to North America. It bears larger fruit (8-13 mm

across), of a bright-red or orange colour, eaten fresh and also used preserved.

The plum is grown relatively widely in the U.S.S.R., ranking third in orchard territory (18 per cent of the total) after the apple and the sour cherry. It is a moderate-sized tree or a bush. The root system spreads close to the surface but far to the sides. The plum thrives best on irrigated or naturally moist lands. Best sites for plum orchards are on gentle, windbreak-protected slopes. In the nonchernozemic zone, the plum trees are liable to get fruit buds and tips of shoots damaged during severe winters or late frosts.

Depending on variety the plums start to bear when 3-4 years old; their longevity is from 20 to 50 years; the per tree yield is up to 100-150 kg and sometimes more. The fruit contains 7-17.7 per cent sugar and 0.2-2.3 per cent acid and is used fresh and dried as prunes, and for jam making.

The more popular varieties, may be divided in three groups as follows: (1) *Vengerki*, e.g., Vengerka Italyanskaya, Vengerka Domashnaya, Goldan Chernaya, Vengerka Azhanskaya; (2) the *Reine Claude* or *Greenage plums*, e. g., Reine Claude verte, Reine Claude d'Altan, Reine Claude Fioletovy, Reine Claude Reforma, Reine Claude Kolkhozny; (3) the *Mirabelles*, e. g., Mirabelle de Nancy.

The plums are mostly grown in Moldavia, Sochi district of Krasnodar Territory, southern regions of the Ukraine, in the Far East, and, to a limited degree, in central regions of the Russian Federation and in the Volga area.

A seat of an indigenous culture of the Myrobolan plum with a highly valuable range of local forms has been preserved in a very small area in the southern Crimea, near Yalta. Mass selection carried over many years by K. F. Kostina (Nikitsky Botanical Garden) on the basis of these forms produced several large-fruited high-quality orchard plums.

The plums belong to one genus, *Prunus* (subfamily *Prunoideae*, family *Rosaceae*), which comprises 34 species growing in the temperate zones of Europe, Asia and North America.

A characteristic feature common to all species of this numerous genus is their shrub-like or small-tree habit. Their root systems spread relatively close to the surface, and many species are very much given to suckering. Their flowers have white petals and slender pedicles, usually remaining with the fruit, which are smooth and glaucous, pendulous,

of variable size, shape and colour. The following species have economic importance.

The blackthorn or *sloe* (*Pr. spinosa* L.). A shrub or a small tree, 4-6 m in height, spreading, making a very thick thorny top, profusely suckering from the root. Young growths are distinctly pubescent. Leaves are small, elongated, very finely serrate; flowers are white; fruits are small, round, black-blue, astringent, usually persisting until winter, scarsely edible.

The blackthorn is common all over Europe, Asia Minor and North Africa. In the U.S.S.R. it grows everywhere to the west of the Urals, and in Transcaucasia and Central Asia. It is very polymorphous, quite a few forms being frost- and drought-resistant.

Some of the large-fruited forms have been domesticated and I. V. Michurin used them for hybridizing with cultivated plums to breed new varieties, such as Tyorn Sladki and Reine Claude Ternovy.

The Myrobolan plum (*Pr. divaricata* Led.). A tree, 4-10 m, or a shrub, up to 1.5 m high, wide-spreading, with a profusion of slender, nearly prostrate branches. Shoots are unarmed; leaves are broader toward the base; flowers are white; fruits are variable in size (usually small), shape (globose or oblong) and colour (yellow, pink, red).

The fruit is used in jam-making and for drying, while the seed goes to grow stocks for cultivated plum varieties.

The species is extremely rich in forms and varieties. For instance, the well-known *Pr. Pissardii* L. and a weeping form, *Pr. pendula* L., are both considered to be forms of Myrobolan plum. There are particularly many forms of this plum in the Caucasus and Central Asia.

The common garden plum (*Pr. domestica* L.). A tree, 6-12 m in height, flat-topped; shoots are glabrous or pubescent, often thorny; sometimes produces root suckers. Leaves are large and thick, ovate or obovate, pubescent beneath; flowers are white; fruits are variable in size, shape (globose or oval-oblong) and colour (yellow, red or blue), and are used fresh or processed (jam-making, drying, etc.) while the seed goes to grow plum-tree stocks.

The wild form has not been found. Many botanists and horticulturists agree that it is a hybrid of the Myrobolan plum and the blackthorn. Some botanists hold that such plums as the bullace or damson (*Pr. insititia* L.), *Pr. oecono-*

mica Borkh., *Pr. syriaca* Borkh., the mirabelle and Reine Claude plums (*Pr. italica* Borkh.) are all forms of *Pr. domestica*. It is evident that the common plum includes a great number of subspecies, varieties and forms which together made it possible to breed the larger part of the orchard plums.

Of great interest for hybridization and breeding are the winter-hardy plums, such as the Ussurian plum (*Pr. ussuriensis*, Kov. and Kost.), the Canada plum (*Pr. nigra* Ait.), the *common American wild plum* (*Pr. americana* Marsh.) and the Japanese plums (*Pr. salicina* Linal. and *Pr. triflora* Roxb.).

The apricot ranks fourth in orchard territory (about 7 per cent). The apricot tree is large, e.g., in Uzbekistan up to 10-15 m in height, or medium-sized, round-headed, thriving in warm areas; because of the very early blooming season it should be planted in localities where spring frosts are not frequent. It is drought-resistant, long-lived (up to 40-70 years) and easy to cultivate. This fruit does best when planted on well-lit elevated land, dry and loamy or gravelly in character.

The apricot tree starts bearing early—the European varieties 3-5 years and the Asiatic varieties 6-8 years after planting—and bears annually in the best conditions, averaging 100-150 kg per tree. The fruit contains 5.5-18.7 per cent sugar and 0.1-2.2 per cent acid, and is used fresh and for canning, drying, jam-making, etc.; when dried the fruit contains 53.5-80 per cent sugar and 1.2-8.5 per cent acid. The seed is used in the confectionary industry as almond substitute, for the production of high-quality edible oil and for growing stocks.

The leading varieties include Krasnoshchyoki, St. Ambroise, Shalakh, Vengerski, Khurmai, Mirsanjali, Shindakhlan, Kursa Aryk, Tovarishch and Lutchy Michurinsky (both by I. V. Michurin).

Commercial apricot-growing is centred in the southern zones of the country, particularly in the Central Asian republics: Uzbek S.S.R., where it accounts for 70 per cent of all stone fruits, and Tajik S.S.R., as well as in Transcaucasia, Krasnodar Territory (the best apricot region in Otradnaya district), the Crimea and Moldavia. Following work done by I. V. Michurin and some other breeders the apricot has been introduced to the central chernozem and the Volga areas.

The genus of the apricot, *Armeniaca* Mill., belongs to the subfamily *Prunoideae* of the family *Rosaceae*, and includes 7 species growing in the wild in China, Korea, the Far East and Central Asia (Tsuin-Shen). The characteristic feature of the genus are: early blooming—preceding the leaves; pink or white flowers without pedicels or with short pedicels; pubescent fruits and vigorous shoot growth. The following species are of importance.

The common apricot (A. vulgaris Lam.). A medium-sized or large tree, 8-15 m in height, with a round spreading top, and extremely vigorous shoot growth. The latter is manifested in an excess of new wood till old age and has to be taken account of in pruning.

The root system is powerful, the fibrous part is not well pronounced, the bark of the roots is cherry-red, leaves are rather large, ovate to round-ovate, short-pointed, glossy. There are several buds to one leaf axil. Flowers are pinkish or white, nearly sessile.

Fruits are variable in shape, usually globular, somewhat compressed, pubescent, yellow or orange, sometimes with a blush; flesh is juicy, aromatic, sweet. Stone is usually free; kernel is sweet, though in some Central-Asian forms it is bitter.

The species is the principal parent form of all European and Central-Asian orchard apricots. It grows wild in Central Asia and China. It is very drought-resistant.

The Siberian apricot (*A. sibirica* Pers.). An upright tree or shrub, up to 5 m high. Leaves are small and glabrous, sometimes sparingly bearded beneath, ovate to rounded. Flowers are white or pink, subsessile. Fruits are small, globular, yellow with a reddish cheek, practically inedible, with a smooth, very sharp-edged stone.

The Manchurian apricot (*A. manshurica* (Max.) Scvortz.). A tree, up to 6 m high. Shoots are unarmed, brownish-grey to brown in colour. Leaves are rounded, strongly double-toothed. Flowers are light-pink, sometimes white, with a long peduncle. Fruits are small, nearly globular, yellow, red-spotted, succulent and sweet, sometimes bitterish. It is a drought- and winter-hardy species.

The Manchurian apricot grows wild to the east of Lake Baikal, in Dauria, Mongolia and in the lower reaches of the Ussuri. I. V. Michurin used it to breed winter-hardy apricot varieties for the central zone.

The peach. The peach is little cultivated—2 per cent in territory. The tree is small, exacting as to warmth and light, does best on deep sandy loams. It is distinguished by high heat-resistance.

The peach tree starts to bear 2-3 years after planting. The yield at the maximum-productivity age is fairly high, up to 20-40 tons per hectare. The period of maximum bearing is from 4 to 15 and more years.

The fruits are large (100-300 g and more), usually coloured, of high quality; contain 6.3-14.9 per cent sugar and 0.2-0.8 per cent acid; ripen from late June to late October; are good fresh, canned and dried. The seed contains 45.0-59.9 per cent of fatty oil.

The peach is an exceedingly variable fruit. Most of the cultivated varieties of peaches (and there are over 5,000 of them) are of the pubescent kind grouped in *true peaches* or *freestones* and *pavies* or *clingstones*. There are considerably fewer glabrous-fruited varieties under cultivation which are grouped in *nectarines* (stone free) and *brugnons* (stone clinging).

According to flesh quality the peaches are divided into three classes: (1) *dessert* or table varieties, e.g., May Flower, Amsden, Greensboro, Inzhirny, Zolotoi Yubilei, Inzhir Shaftalyu, Kievski Ranni; (2) *dessert* and *drying varieties*, e.g., Nikitski, Champion, Elberta, Roht Front, Nectarin Bely; (3) *canning varieties*, e.g., Brussky, Goriisky Bely, Salwey, Khidistavsky Rozovy, Molozani, Zafrani, Narinji, Kazevadse.

Peach plantations are centred in the southern zones of the country, particularly in the Central Asian republics (21 per cent of all stone fruits in Uzbekistan), in Transcaucasia, Northern Caucasus, Moldavia, southern Ukraine, where some new varieties show promise for cultivation in more northerly and westerly areas.

The genus of the peach, *Persica* Mill., belongs to the subfamily *Prunoideae* of the family *Rosaceae*. A total of 6 species are known in the wild in China and, probably, in Tibet. Only one species, the common peach, and partly the David peach are of economic importance.

The common peach (*P. vulgaris* Mill.). A small tree, 3-5 m in height, sometimes a shrub, upright-spreading, open-topped and with a rather deep root system. The leaves are relatively large, oblong-lanceolate, coarsely serrate,

usually glabrous. Perioles are usually gland-bearing. Wood and fruit buds are borne in twos or threes, sometimes singly, in the axils of leaves. Flowers are numerous, nearly sessile, white or pink, appearing before the leaves. Fruits are variable in size, shape, colour of skin and flesh; skin is pubescent or glabrous; flesh is juicy, sweet or mildly subacid, of good quality; stone is large, free or clinging, deep-pitted and furrowed very hard. There are bitter-kernelled and sweet-kernelled forms.

The wild form is not known though it is believed to exist in Central China. A run-wild form occurs in Central Asia and the Caucasus. The species is considered to be the progenitor of all the cultivated varieties of peaches.

The David peach (*P. Davidiana* Carr.) is an ornamental tree, up to 8 m high. Flowers are solitary, sometimes in pairs; fruits are globose, small, inedible. The wild form grows in Northern China. The species is hardy to frost, drought and heat which qualities were used by I.V. Michurin in hybridizing it with the almond and the orchard peach.

Nut Plants

The walnut. The walnut is little cultivated (1.7 per cent of orchard territory). The walnut tree is large, with a deep and powerful root system. It is rather tender and does best on deep, rich, medium-dense soils. The trees start bearing when 5-6 years old, but appreciably so from 10-15 years. The per-tree yields reach 100-300 kg and more. The fruits, walnuts, are very nutritious, the kernel containing up to 75.6 per cent oil and up to 22 per cent protein.

The leading varieties include Ideal, Kurzim, Maiyet, Franket, Shaberteh, Krupny, Urozhainy.

The walnut plantations are centred in the southern zones of the U.S.S.R.: the Central Asian republics, especially Uzbekistan and Azerbaijan, Daghestan, the Crimea and Moldavia.

The genus *Juglans* belongs to the family *Juglandaceae*. It includes 12-15 species growing in the Northern Hemisphere, of which the more important are the walnut and the Manchurian and black walnuts, and the butternut. The species of the genus *Juglans* are usually represented by large, vigorous, broad-headed trees, sometimes by small trees and rarely shrubs; the leaves are large, deciduous,

odd-pinnate, with 3-21 leaflets; the flowers are diclinous; the plants are monoecious. The pistillate flowers are solitary appearing on yearling wood terminally, with the staminate flowers in pendulous catkins immediately below, Pollination is carried out by wind. The fruit is a large drupe. with a fleshy, inedible exocarp and a hard endocarp (the shell), which harbours the seed (the kernel). The following are the more widespread species.

The walnut or *English walnut* (U.S.) (*J. regia* L.). A large, up to 25-30 m in height and 1.5-2 m in trunk diameter, with a huge round top. Its longevity is 200-300 years. Fruits are varying in size from a small cherry to a large plum, and are usually ovate or globose.

The seeds are rich in oil, 50-77 per cent, and protein, 15-22 per cent, and contain 1-7 per cent carbohydrates (V. A. Kolesnikov, 1941); and are used raw and processed.

The walnut grows wild over vast territories (over 100,000 hectares in Kirghizia, Tajikistan, Kazakhstan and Uzbekistan) and is cultivated in the Caucasus, Transcaucasia, the Crimea and Moldavia. This species is the parent of all the cultivated varieties of the walnut.

The Manchurian walnut (*J. manshurica* Maxim.). A large broad-headed tree, up to 20-25 m in height, with deeply furrowed bark on the trunk and branches. The root system is of the tap-root kind, with deep penetration, owing to which this walnut is relatively drought-resistant. Fruits are single or in short racemes of 3-7. Both the exocarp and endocarp are thick; seed is small, hard to extract, nutritious, of good quality, containing up to 55 per cent of fatty oil. The Manchurian walnut is of chief value for timber and ornamental planting. It is winter-hardy and is used as a stock for *J. regia.*

The species grows wild on considerable territories in conifer-broad-leaved forests of Primorye Territory and in Manchuria. There are several subspecies.

The black walnut (*J. nigra* L.), native of North America, and the butternut or white walnut (*J. cinerea* L.), native to East Asia, are winter-hardy, ornamental and timber trees, large, with small edible seed, rather hard to separate from thick shells.

The last three species are of value because they are winter-hardy and can be used as a stock for and in hybrid work with *J. regia* which is considerably less hardy.

The pecan. The pecan tree is large and vigorous, rather exacting as to warmth and moisture and requiring deep, fertile soils. It has better cold endurance than the walnut It is usually propagated by seeds, stratified and sown in spring, by budding and grafting.

The per hectare yields are up to 3-4 tons, which can be processed into 1.5 and more tons of valuable nut oil. The kernels contain 45.5-77 per cent oil and 8-18.9 per cent protein. The pecan has much to commend its wider cultivation in the U.S.S.R.

The leading varieties are Schley, Stuart, Success, Moor, and Moneymaker, all of North American origin. Most of the pecan orchards are in Transcaucasia, Northern Caucasus (particularly round Gagra) and in the Crimea.

The genus of the pecans or hickories, *Carya* Nutt., belongs to the family *Juglandaceae*. About 20 species, all native to North America and South China, are known. Closely related to the genus of the walnut, it has many characters in common with it. The main differences are in that the male and female flowers of the hickories have no perianth, while their nuts have poorly developed ridges or no ridges at all. Only one species is of economic importance.

The pecan (*C. olivaeformis* Nutt.). The pecan tree attains very large size, with heights ranging from 30 to 60 m and trunk diameters up to 2 m, with a powerful round top and sturdy boughs. It is long-lived. Leaves are large, 10-18 cm long, odd-pinnate, of 9-17 oblong-lanceolate leaflets. Male flowers are in hanging catkins, and female flowers in small 3- to 4-flowered clusters. Pollination is by wind. Nuts, 5-8 cm long, globular or oblong, are in clusters of 3-10; shell is thin; kernel is sweet and of excellent quality.

The pecan grows wild only in North America. It was introduced to Russia at the close of the last century and now occurs along the Black Sea coast of the Caucasus, in Transcaucasia, and more recently in Uzbekistan. It is valuable for commercial nut production, as well as for timber, windbreak and highway plantings.

The cultivated hazelnut—filbert and cobnut. These nuts are little cultivated in the U.S.S.R. so far (1.0 per cent in orchard territory). It is a medium- or large-sized deciduous shrub. The root system is of a surface type, fibrous. The top system consists of 10-20 stems, largely owing to ex-

tensive formation of suckers. It does well on irrigated, moist loamy, marly and clayey soils. Bearing begins 4-5 years after planting. At the maximum-productivity age (15-20 years) the yields may reach 3-5 tons per hectare. The nuts are valuable for their high fat-content (up to 70 per cent).

Some of the best known varieties are the following: Cherkessky Krugly, Kudryavchik, Kerasund Krugly, Kerasund Dlinny, Badem, Lombardsky Belly, Furfulak, Barcelona.

They are mostly cultivated in the southern zones, particularly in Zakataly district, Azerbaijan, which accounts for at least three quarters of the cultivated hazelnut acreage of the U.S.S.R. It is a most valuable nut plant which should be grown beyond its present northern boundary, in the central zones (particularly the varieties evolved at the Michurin Central Genetical Laboratory).

The genus of the hazelnut, *Corylus* L., belongs to the family *Betulaceae* and includes 15 species growing in Europe, Asia and North America of which 10 species are found in the U.S.S.R. The trees or shrubs are monoecious; the flowers are unisexual. The female flowers appear terminally, on yearling wood, with the male flowers as catkins immediately below. Pollination is by wind. The fruit is a one-seeded nut with an exocarp formed of united bracts and bractioles. The following are the better known species.

The hazelnut (*C. avellana* L.). A shrub or an intermediate, tree-like form reaching 6-9 m in height, with a large number of separate stems and a shallow fibrous root system. Leaves are variable in form, orbiculate or elongated, doubly serrate, nearly glabrous above, pubescent beneath. Catkins are in clusters of 2 to 3, sometimes 5. Blooming is early, in the warm days in February-March, much in advance of leafing. Nuts are variable in shape, usually roundish-ovate, small; kernels are edible.

The hazelnut grows wild in the U.S.S.R. in shrubby thickets occupying an estimated one million hectares. It is most spread in the European part of the U.S.S.R. and in Transcaucasia, the Caucasus and the Crimea. The thickets are rich in varietal forms valuable for the wild crop, windbreak and shrubberry plantings and for the selection of best parents for breeding and hybridization.

The filbert (*C. maxima* Mill.). A bush, sometimes a tree, up to 3-10 m in height, with relatively erect stems.

Its distinguishing features are oblong nuts and involucres, and sometimes the reddish colour of the foliage. It is less winter-hardy than the common hazelnut. It occurs on considerable areas on the Black Sea coast of the Crimea and the Caucasus, particularly in Abkhasia. It is valued for high productivity, and the attractive appearance and excellent quality of the nut. The species is cultivated.

The cobnut (*C. pontica* Mill.). A shrub reaching 4-6 m in height. The distinguishing features of the species: leaves usually roundish; involucre longer than the nut, with much divided spreading lobes; nuts large, broad-ovate, with kernel not filling the whole shell. It grows on the Black Sea coast of the Caucasus and the Crimea, and is valued for the large size of the nut, a feature that should find more use in nut hybridization and breeding. Some authors treat this species as a variety of *C. avellana.*

These three species are the parents of the numerous cultivated varieties of Corylus nuts.

The almond. It is little cultivated (0.3 per cent of orchard territory). The almond tree is small- or medium-sized (3-6 m or more) with a deep root system. It is tolerant of heat and drought and can stand drops in temperature down to —25°C in winter, but it requires warmth in summer and should be planted on higher and drier lands with deep loose lime-rich soil.

The almond trees start bearing 3-4 years after planting and live to 40-50 years. In good conditions a 25-30 year old tree will yield 100 and more kg.

Apart from the hard-shelled varieties some highly valuable soft-shelled ones (the thinnest-shelled forms known as *paper-shells*) with 40-50 per cent oil content have been evolved in the U.S.S.R., mostly in the Crimea. Depending on variety and locality oil content in almond nuts varies from 40 to 70 per cent. Almond nuts are eaten out of hand or processed: the sweet-kernelled in the confectionary industry and the bitter-kernelled in the manufacture of flavouring extracts; the latter are used for growing rootstocks.

Some of the best known varieties are the following: Bumazhnoskorlupy, Sovetsky, Nikitsky No. 62, Yaltinsky, Krimsky, Nonpareil, and Dessertny.

The almond plantations are centred in the southern zones of the U.S.S.R., particularly in Central Asia, Transcaucasia and the Crimea.

The genus of the almond, *Amygdalus* L., belongs to the subfamily *Prunoideae* of the family *Rosaceae*. About 40 species are known, growing wild in warm-temperate and subtropical zones, the Mediterranean basin, Middle and Central Asia, Mongolia and central highland China. Out of the 16 species established in the U.S.S.R. only the common almond and partly the Russian almond are of economic importance.

The common almond (*A. communis* L.). A small tree or shrub, 4-5 m in height, round- or sometimes pyramid-headed, with numerous unarmed branches and a deep powerful root system. The species is very drought-resistant and an early bloomer. Leaves are lanceolate, very closely serrate or entire. Flowers are relatively large, pink, solitary and appear before the leaves. Fruits are oblong, compressed, pubescent, sometimes glabrous; mesocarp is dry, inedible, splitting open at maturity; stone is oblong, hard, sometimes soft or paper-shelled; kernel is bitter, sometimes sweet.

The species grows wild on vast territories in Western Tien-Shan and Western Kopet-Dag, and in Transcaucasia, the Caucasus and the Crimea. It is the parent of all the cultivated almond varieties.

The Russian almond (*A. nana* L.). A bush, 1-1.5 m high. Leaves are narrowly elliptic, smooth, with saw-toothed edges. Flowers are profuse, rose-coloured, appearing simultaneously with or just preceding the leaves. Fruits are small and hard, pubescent; kernel is inedible. It grows in the wild in the steppe areas of Altai Territory. It is very winter-hardy and was used by I. V. Michurin to obtain an intermediate hybrid by crossing it with the wild David peach.

The pistachio. There are still few pistachio plantings in the U.S.S.R. The pistachio is a tree, 2-10 m high. When once established, it requires little irrigation and is drought-, heat- and winter-resistant, surviving brief spells of frost down to —30°C.

The trees start bearing in the third to fourth year from graft. In good conditions a 30-40-year-old tree may yield up to 35 kg of nuts. The best varieties may have a kernel nut ratio of 55 per cent, and contain 65 per cent oil and 23 per cent protein.

The best known varieties are the following: Akhòri, El Baturi, No. 165, No. 167, Apsheronskaya, Kishlinskaya,

There are pistachio plantations in Azerbaijan, Daghestan and Georgia; in recent years it has been introduced to the Crimea and Moldavia. The pistachio is much cultivated in Asia Minor, Middle East, India and Sicily. This nut merits extensive study, with a view of breeding new varieties and increasing its plantings.

The genus of the pistachio, *Pistacia* L., belongs to the family *Anacardiaceae*. About 20 species and 10 varieties of the pistachio are known growing in East Asia, Mexico and Southern Europe including 2 species in the Soviet Union: *P. vera* and *P. mutica*.

The pistachio (*P. vera* L.). A tree, up to 9 m high, with spreading branches, often multi-stemmed, with a deep taproot system; very drought-resistant and long-lived, up to 300 years, sometimes more. Leaves are deciduous, pinnate, with 1-5 pairs of leaflets. Flowers are dioecious, both staminate and pistillate ones in panicles, appearing before the leaves; pollinated by wind. Fruit is a dry drupe, 0.8-2 cm long; kernel is green, of an agreable flavour, and rich in oil and protein. The pistachio trees are grown for their edible nuts and for the extraction of turpentine and valuable resins.

The pistachio grows wild on vast territories in the Central Asian republics, particularly in Tajikistan, Turkmenistan, Kazakhstan and Uzbekistan, and in Iran and Asia Minor. The species has everything to commend it for wide use in timber, windbreak, park and roadside planting.

P. mutica Fisch. and Mey. grows in Turkey and in the Crimea (Alushta district) where it attains the height of 10-20 m. It is valuable for timber, resin, and as stock to graft the commercial pistachio species.

The sweet chestnut. It is a large tree with a powerful surface-type root system. It requires sufficient light, warmth (not lower than 20-25°C below zero) and moisture, and rich soil. The grafts begin to bear in the third-sixth year, and at the age of 50 years, in optimum conditions and good care, should yield over 70 kg of nuts. Dried nuts contain 16-34 per cent starch, 4-14 per cent sugar, 8-11 per cent nitrogenous substances and 2.3-9.5 per cent oil; they are used raw and roasted as well as processed (as flour, etc.).

There are few chestnut plantations in this country, far less than chestnut-culture merits. In the U.S.S.R. the

sweet chestnut is cultivated in the Caucasus, Transcaucasia, the Crimea and Moldavia. It is extensively cultivated in Italy, France and Spain.

The genus of the chestnut, *Castanea* Mill., belongs to the family *Fagaceae*. The genus comprises 10-12 species spread in the temperate regions of Asia, North America, North Africa and Southern Europe; altogether 5 of them are cultivated. The species most esteemed is the sweet chestnut.

The sweet chestnut (*C. sativa* Mill.). A large vigorous round-headed tree, 20-35 m in height and 2 m in trunk diameter; long-lived (300 years, sometimes considerably more). Leaves are oblong-lanceolate, coarsely serrate. Flowers are monoecious, in yellowish-white catkins, appearing on the current season's growth on the outer boundary of the head. Fruits, one-seeded nuts, are usually 3 together in a hard prickly involucre of bur which cracks on maturing, they are compressed, enclosed in a thin skin, edible, sweet and rich in starch.

The sweet chestnut grows wild in the Caucasus, Transcaucasia (on a territory of about 70,000 hectares) and Asia Minor, and is cultivated in Southern Europe and the south of the U.S.S.R. Of great interest for selection and breeding of improved varieties are the following species of Castanea: *C. dentata* Borkh. (the American chestnut), very winter-hardy; *C. pumila* Mill. (the common chinquapin of North America), precocious; *C. crenata* Sieb. and Zucc. (the Japanese chestnut), cultivated in Adzharia and *C. mollissima* Bl. (the Chinese chestnut). Some of these have occasionally been used by breeders, e.g., by L. Burbank.

Subtropical Fruits

The olive. The cultivated olive (*Olea europaea* L.) is a medium-sized tree, 5-8 m high, but may reach 22 m and more. It bears small oblong or lanceolate evergreen leaves and axillary forking racemes of yellowish white fragrant flowers. In the U.S.S.R. the olive is still very little cultivated (about 200 hectares), but there are plans to increase olive-plantation territory greatly.

The species is very drought-resistant and can survive brief spells of frost not lower than —10-18°C. It is fairly

tolerant of a variety of soils so long as they are not wet clays with high-standing ground water, and can even stand a certain salinity; however it prefers loose sandy loam soil with a sufficient content of lime. The trees begin to bear at the age of 4-10 years and later, and reach maximum productiveness between 15 and 50 years.

The olive trees keep up commercial production till an average age of 200 years and may live much longer. The yield may reach 50 and more kg per tree. The fruits weigh between 1.5 and 13.5 g; they are inedible but make a delicious food when pickled. They contain from 30 to 75 per cent of dry-weight of excellent olive oil. It is golden-yellow, transparent, of excellent quality and considered to be the best vegetable oil on the market. Besides, the olives contain proteins, sugars, ash elements, vitamins B and C, and pro-vitamin A.

About 500 cultivated varieties of the olive are known in the Mediterranean basin, of which the U.S.S.R. has about 80. The leading cultivated varieties include (1) home varieties, e.g., Nikitskaya, Krymskaya, Kolkhoznitsa, Bakinskaya Nos. 8, 17 and 25 and (2) imported varieties, e.g., Agostino, Ascolano, Della Madonna, Correggiolo, Santa Caterina.

Apparently olive culture has been started on the territory of the U.S.S.R. a long time ago. Individual trees of over 200 years are recorded in Azerbaijan (on Apsheron Peninsula), of 500 years in Georgia and considerably older on the southern coast of the Crimea. At present the olive is cultivated in Azerbaijan, Turkmenia, Georgia, Krasnodar Territory (on the Black-Sea coast) and the Crimea. So far there are few big olive-only plantations but mostly small plantings or separate clumps of trees. The biggest olive plantations are in Spain, Italy, Portugal, Turkey, Tunisia, Australia and Argentine. It is a highly valuable crop and should be more extensively cultivated in the U.S.S.R.

The genus of the olive, *Olea* L., belongs to the family *Oleaceae* and includes 30-40 species growing in the Mediterranean countries, Africa, Indonesia, Australia and New Zealand. All the species are evergreen tree or shrub forms. Only one species is cultivated, *Olea europaea* L. (Fig. 25). There is a closely related wild form, *O. europaea var. Oleaster* DC.

Several wild forms have edible fruit, e.g., *O. chrysophylla* Lam., a tree, 4-12 m high, with spiny branches. Leaves are thick, lanceolate; flowers are small, white; fruit is a one-seeded drupe, oval- or ball-shaped. It grows

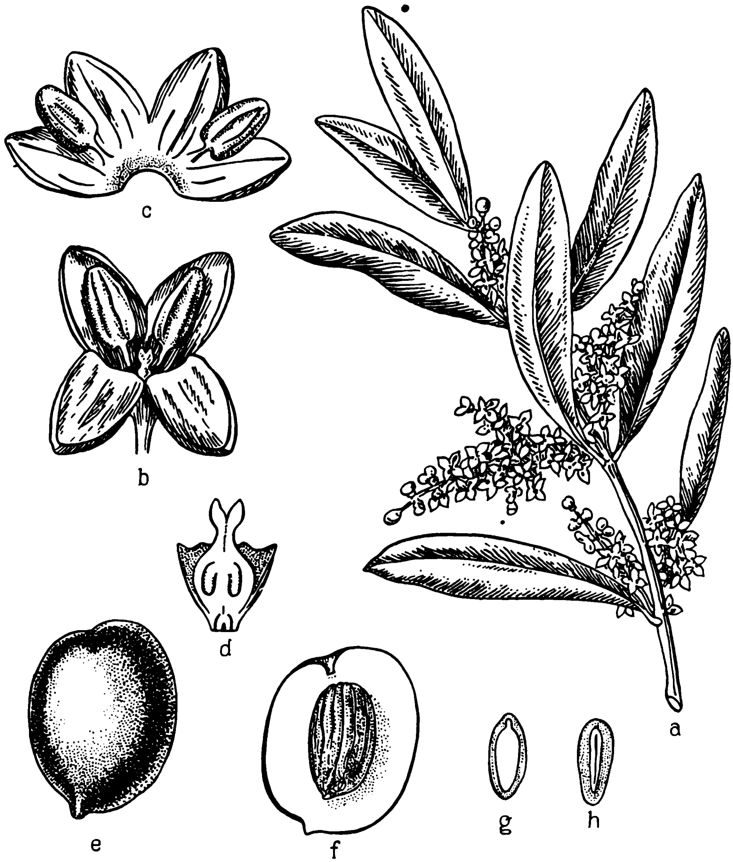


Fig. 25. Reproductive organs of olive:

a—flowering branch; *b*—flower; *c*—corolla with stamens; *d*—pistil (in section); *e*—fruit; *f*—fruit (in section); *g*, *h*—longitudinal sections of seeds with hard skin removed, (after V. Suleimanov)

wild in mountain regions from the Himalays to the Atlantic Ocean and the south of Africa. The species served as parent form for the numerous cultivated varieties.

The persimmon or date-plum. It is a deciduous tree reaching a height of up to 15 m. The persimmon does fairly well on almost any soil, but it will give best results if planted on deep, well-drained rich loams. It is cultivated (only *Diospyros Kaki* and on small territories) in Georgia, Azerbaijan, the Crimea and in Central Asian republics. The experimental plantings of this species in Moldavia and the south of the Ukraine have shown enough promise to warrant their great increase in those areas.

The persimmon is propagated by budding and grafting on seedlings of *D. lotus* and, in regions with colder winters or wetter land, on those of *D. virginiana*.

The persimmon comes into bearing 3-4 years after planting. The trees may live and bear crops until they are 100 or more years old. They are annual bearers. A tree may produce 150 to 250 kg of fruit. The fruits weigh 100-500 g and are sweet and of good quality; they are eaten out of hand or as a sweetmeat when dried, and can be also used in jam- and liqueur-making. Some of the varieties ship well. They contain 17 to 26 per cent sugar, 0.01-0.3 per cent acid, 0.3-1.6 per cent protein, 0.4-0.85 per cent oil, 0.6-0.72 per cent ash and up to 42 mg vitamin C. The dried fruit contains up to 62 per cent sugar.

The Chinese date-plum or persimmon was first imported into the U.S.S.R. in 1888 when it was planted in Sukhumi, Georgia. From there it spread to Azerbaijan, Daghestan, Armenia, the Crimea, Krasnodar Territory (the district of Sochi) and Central Asian republics. The species is indigenous in China where it is extensively cultivated, the same as in Japan, the Mediterranean regions and North America.

There are many varieties of the persimmon (about 100 in the U.S.S.R.), which usually require the planting of pollinator trees, but certain varieties such as the Hachiya and Tane-Nashi bear fruit without pollination, i.e., by parthenocarpy. The leading varieties are: Meotse-sankune, Hachiya, Hyakume, Costata, Tsuru No-Ko, Tamopan, Seedless, Tane-Nashi.

The genus of the persimmon, *Diospyros* L., belongs to the family *Ebenaceae* and includes about 200 species found almostly exclusively in the tropics; the few exceptions grow in the subtropical and temperate zones. The latter are represented in the U.S.S.R. by three species.

The Chinese date-plum or persimmon, Japanese or *Kaki persimmon* (U. S.) (*D. Kaki* L.). A tree, up to 8-15 m high, with a round head, long-lived. Leaves are large, variably ovate, entire, deciduous. Flowers are sometimes hermaphrodite, but usually dioecious, yellowish-white; male flowers with 16-24 stamens are in clusters, female flowers are long, usually solitary, borne terminally. Fruit is a large berry, ovoid to depressed-globose, tomato-red or orange and waxy; ripe flesh is jelly-like, juicy, of dessert quality; there are 8 to 10 large seeds or none at all. The species grows wild in China.

The date-plum (*D. lotus* L.). A large tree, up to 20 m high. Fruits are edible and, as distinct from the Chinese date plum, are small, yellow, and many-seeded. It grows wild in Transcaucasia, chiefly in Lenkoran and Astari Regions of Azerbaijan, and in the Crimea.

The North-American ebony or persimmon (*D. virginiana* L.). A large tree bearing small, edible fruit. It grows wild in Virginia, North America.

Both latter species are grown for their edible fruits and also used as seedling stock on which to graft or bud the Chinese date-plum.

The fig is a subtropical, deciduous tree up to 10-12 m high, usually with several stems, or a bush, with large leaves. It is drought-resistant, intolerant to cold and is damaged by frosts below 12-15° C. It is very easily propagated from hardwood cuttings. The fig is dioecious. It normally blooms and bears fruit twice or more in one growing season. It comes into bearing 2 to 3 years after planting and lives till it is 50-60 years old, the maximum productivity being 50-100 or more kg. The fruit is a berry-like infructescense and weighs 30-100 or more g. The fruits are eaten in the fresh state, and are also dried and preserved. They cannot be shipped. Sugar content is 25 per cent when harvested and 70 per cent when dried.

The leading varieties are Smena, Dalmatica, Livadiisky, Sochinsky Nos. 4, 7 and 15, Sary Inzhir, Smirnsky No. 2, Cadota and Sary Lob.

The fig is grown in large plantations, as an interplanting culture and in home yards. It is cultivated unsheltered for winter on the Black Sea coast of the Caucasus (from Tuapse down to Batumi), and in the warmer regions of Armenia, Georgia, Azerbaijan, Daghestan, the Crimea, and Turkme-

nia, and sheltered for winter, in the other Central Asian republics.

The genus of the common fig, *Ficus* L., belongs to the family *Moraceae* which includes 600-800 species mostly growing in the tropics and partly in the subtropical and temperate zones. Out of the subtropical species only one is of great economic importance.

The common fig (*F. carica* L.). A medium- or large-sized tree, up to 15 m in height, sometimes a many-trunked, round-headed bush; it is long-lived (to 100 or more years). Leaves are 3-5-lobed, rarely undivided, 10-20 cm long and about as broad, with palmate veins, deciduous. It is dioecious. It grows wild or run-wild in Transcaucasia, the Crimea and Central Asia, particularly Turkmenia; also in Iran, Asia Minor and the Mediterranean regions. It is considered to be native to West Asia.

The pomegranate is a subtropical deciduous tree or a large, many-trunked bush, with slender, twiggy branches and small, oblong leaves. It is drought- and heat-resistant, but intolerant to cold, being injured by frosts below 12-16°C.

The pomegranate is propagated by hardwood cuttings or by layers, more seldom by grafting.

The pomegranate begins to bear 2-3 years after planting and lives until it is 30-40 years old. Yields in best localities may reach 50 or more kg per plant. The fresh fruit is of exquisite quality; it consists of 28-42 per cent seed (400-700 per fruit) and 36-41 per cent juice which contains 10-20.5 per cent sugar, 1.5 per cent protein, 3 per cent oil and 0.55-5.4 per cent citric acid. The juice is used to make syrups, a cooling drink named grenadine and a wine.

The leading varieties are Ak Dona, Kima Anor, Shogulyansky, VIR No. 1, Nikitsky Ranny.

It is cultivated in Azerbaijan, Armenia, Central Asian republics (Uzbekistan, Tajikistan and Turkmenia), Daghestan and the Crimea.

The pomegranate should be more extensively planted as an interplanting culture, and in shelter belts, parks, health centres, schools and home yards.

The genus of the pomegranate, *Punica* L., belongs to the family *Punicaceae*. The genus includes only two species of which one is commonly found wild.

The pomegranate (*P. granatum* L.). It is a small branched tree or a large shrub, up to 2-5 m in height, suckering rath-

Fig. 26. Flowering shoot of pomegranate:
a—long pistillate flower and bud; *b*—shortly pistillate flower and bud

er abundantly, relatively long-lived (up to 50-70 years). Leaves are small, with oblong or obovate, obtuse, entire, glabrous, deciduous. Flowers are large, orange-red, bisexual, solitary or 3-5 together, many stamens and one pistil; they are dimorphous, the two forms, depending on pistil shape and blooming time, being: (1) the bell-shaped, shortly pistillate ones; the pistils of these flowers are not fully developed, do not form ovaries and all of them fall; and (2) the ascidiform, long pistillate ones; these flowers mostly give fruit. It is cross-pollinated (Fig. 26).

The fruits are large, up to 8 cm in diameter, subglobose; seeds are numerous, each enveloped by juicy nutritious pulp; leathery pericarp is yellowish-pink or red. Age-long domestication has led to the enlargement of the fruits to diameters of up to 18 cm and weights of 200-800 g in some varieties.

The pomegranate grows wild in Central Asia, Transcaucasia, Daghestan, Middle East, Asia Minor, Iran and Afghanistan.

The feijoa. It is an evergreen shrub of an ornamental appearance up to 4.5 m in height. The leaves are rather small, elliptical, the upper surface glossy green and lower surface silvery grey. The flowers are external, single, bisexual; the petals are fleshy and edible in salad. The feijoa is not winter-hardy and is seriously injured by temperatures of 12-13°C below zero. The plant is fastidious as to soil and requires sufficient moisture.

The feijoa is propagated by seed and by layers. Seedling trees start to bear 3-4 years after sowing, the clones 2-3 years after planting, with a full crop after 7-8 years. The yields average 20-25 kg per shrub. The fruit is a berry, the size of a large plum, dull green in colour, aromatic, sweet, of an agreeable flavour; it contains 6.1-10.5 per cent sugar, 1.5-3.6 per cent malic acid and 2.1-3.9 mg iodine per 1 kg of fruits. The fruits are eaten fresh and as marmalades, jams, jellies; the juice can be distilled into a liqueur.

The best known varieties are Svetly, Nikitsky, Bugristy, Pervenets, Ranny Aromatny, Krupnoplodny.

The feijoa is cultivated on the Black Sea coast of the Caucasus and the Crimea. It is a valuable plant and deserves being more extensively cultivated.

The genus of the feijoa, *Feijoa* Berg., belongs to the family *Myrtaceae* and includes 3 species, all native to Brazil, of which one has economic importance.

The avocado. A large tree, up to 18 m in height. In the U.S.S.R. there are several avocado plantings of 1934 where trees have reached a height of 12 m. The avocado is a native of humid subtropics and is intolerant to drought and cold; frosts of 4 to 6°C may damage its leaves and branches. The leaves are persistent, elliptic-lanceolate to oval, thick, large (10-25 cm long). The flowers are external, in broad compact panicles; cross-pollinated.

The avocado is a fast grower, long-lived (up to 100 years); it starts to bear when 3-5 years old and may yield between 600 and 1,000 fruits per tree. The fruit is a one-seeded drupe, 5-20 cm long. The flesh of the fruit, which comprises 65-85 per cent of the total weight, contains 9.8-26 per cent oil, 1.6-2.1 per cent protein, 1-1.8 per cent ash, 60-70 per cent moisture, provitamin A, and vitamins B, C, E and D. The fruits have a delicious flavour and are eaten fresh, salt or sugar being sometimes added.

The varieties cultivated in the U.S.S.R. are Mexicola, Puebla, Duke, Ganter, Blackberdt, Nortrone, Fuerte, Caliente. The first attempts to introduce the avocado into Russia date back to 1904.

The avocado is quite valuable and following some work to increase its hardiness should be cultivated more extensively in the U.S.S.R.

The genus of the avocado, *Persea* Gaertn., belongs to the family *Lauraceae* which includes 50 species growing in tropical and subtropical America and the Canaries; the most widespread species is *Persea gratissima* Gaertn. which served as the main parent form for the cultivated varieties. It is a large evergreen tree, up to 18-20 m in height. The leaves are alternate, oblong-lanceolate, 10-25 cm long. The flowers are yellowish-green, bisexual, in panicles. The fruits are 4-20 cm long, pyriform, with one large seed.

Of the other *Persea* species *P. Schiedeana* Nees. grows wild and is cultivated in Central America and southern Mexico, *P. Borbonia* Spreng. grows naturally as far north as North California, and *P. indica* Spreng. is found on Madeira, the Canary Islands and the Azores. The latter two species are of ornamental value and may presumably be useful as a rootstock on which to graft the cultivated avocado.

The loquat. The genus of the loquat, *Eriobotrya* Lindl., is in the family *Rosaceae.* Out of 10 species only one is known in cultivation in the Caucasus and the Crimea, and in southern China, India, Japan and the south of Europe.

The loquat (*E. japonica* Lindl.) is a small tree with large persistent leaves. Fruits are pear-shaped, yellow, about 4 cm long, with few large seeds, of agreeable acid flavour; they are used fresh and as a condiment. The loquat is also an excellent decorative plant.

There are a few other subtropical fruit plants in the U.S.S.R. still very little cultivated, viz.:

The cherry laurel. It is a small tree (reaching 6 m in height) or shrub grown for its edible fruits or as an ornamental plant, with handsome evergreen foliage; the bark on the trunk and branches is smooth and greyish-brown. The leaves are large, dark green, coriaceous and glossy. The flowers are small, white, in short racemes. The fruits vary from very small to the zise of a sweet cherry one seed. The skin is pinkish-white to black. The flesh is edible, of good quality (Fig. 27).

Fig. 27. Cherry laurel leafe, inflorescence and fruits

The leading varieties are Sladkaya Rozovaya, Chernoplodnaya, Rannaya Sladkaya, Chernoplodnaya Sladkaya "Nakipu", Sladkaya Beloplodnaya.

The cherry laurel is cultivated on the Black Sea coast and in western Georgia.

The cultivated species is *L. officinalis* Roem. (genus *Laurocerasus*, the family *Rosaceae*), which has many forms. It is native to Asia Minor and Georgia. It is an ornamental plant and has medicinal value. It is grown in the orchards and parks on the coast of the Caucasus and the Crimea.

The papaw, (*Asimina triloba* Dun.) of the family *Anonaceae*. A small ornamental spreading tree with large (15-30 cm long) deciduous leaves. The fruits are oval to oblong, up to 100 g in weight. The flesh is sweet, containing about 18.4

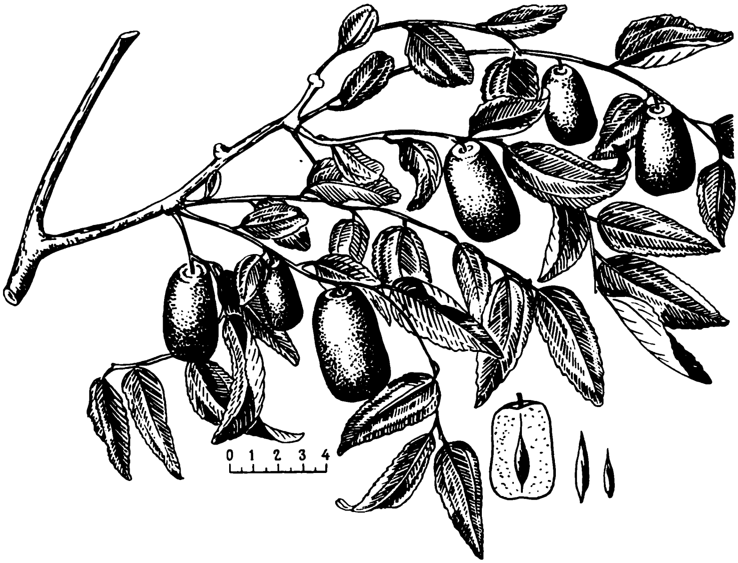


Fig. 28. Lang jujube fruiting shoot, cross section of fruit, and seed

per cent sugar, of agreeable flavour and pineapple-strawberry fragrance. The fruits are eaten fresh and dried, and used for jam-making. The yields may reach 10 t per hectare.

The papaw is relatively hardy. It grows best in rich and humid soil. In the U.S.S.R. it does best in the humid subtropics of Transcaucasia.

The jujube. The jujube of Chinese origin has been cultivated on the territory of the U.S.S.R., e. g., in Central Asia, for over a century now. Five large trees are recorded in Daghestan, all of them about 100 years old and averaging yields of 70 kg per tree (A. D. Strebkova, 1949). In 1930 the jujube was introduced from California to Abkhasia on the Black Sea coast and its behaviour studied (A. I. Kolesnikov). In 1934 a shipment of Chinese forms of the jujube was planted in Azerbaijan and in 1953 in the Crimea (Fig. 28).

Planting of the jujube by collective farms of Uzbekistan is planned. Experiments have shown both economic advantage and feasibility of a jujube culture in Central Asia

(L. T. Tashmatov, 1959). In Central Asia there are 14-year-old trees reaching 7-9 m in height. Their fruits weigh 11-14 g; bearing is annual, heavy, averaging 25-30 kg per tree. At the age of 10-15 years the trees may yield up to 20 tons per hectare. The jujube fruits contain on the average 55.25 per cent sugar, 2.93 per cent protein, 1.73 per cent ash, 13.44 per cent moisture and 26.65 per cent other substances. The fruits have also vitamins C and A.

The leading varieties are the imported Lang and Li, and those evolved in Azerbaijan and Soviet Central Asia: Kitaisky Nos. 1, 2 and 3, Azerbaijansky No. 22, Apsheronsky, Mardakyansky No. 1, Tajiksky No. 24 and Shirvansky.

The jujube can be cultivated in all subtropical regions of the U.S.S.R. and in Central Asia (Ferghana Valley, Uzbekistan and the vicinity of Ashkhabad), in Daghestan and southern Ukraine.

Outside the U.S.S.R. the jujube is mainly cultivated in China, India, the U.S.A., Mexico and the Mediterranean countries.

The jujube belongs to the genus of *Zizyphus* Mill. (family of *Rhamnaceae* R. Br.). The genus comprises about 50 species spread in the tropical, subtropical and partly the warm-temperate zones of both hemispheres. In the U.S.S.R. some of the species grow naturally in the Caucasus and Central Asia. The genus is represented by deciduous and evergreen shrubs and trees. The most valuable is *the jujube* (*Z. jujuba* Mill.). A deciduous shrub or tree up to 9-15 m in height, leaves 3-7.5 cm long, flowers small, fragrant; fruit is a fleshy drupe 1-2 cm long. It grows in the Mediterranean, China, Japan, etc. There are several forms.

The Japanese raisin-tree (*Hovenia dulcis* Thunb, of the *Rhamnaceae*). A small tree, up to 10 m high, or a shrub. Leaves are broad-ovate or elliptic, serrate, sometimes nearly entire, almost glabrous, 10-15 cm long. Flowers are in many-flowered cymes. Fruits are small, globular, on reddish, fleshy and edible peduncles.

H. dulcis is native to Japan, China and the Himalayas where it is cultivated. It is grown in Transcaucasia, on a small scale, for its edible fruit peduncles and as an ornamental shrub.

The date palm. (*Phoenix dactylifera* L., of the family *Palmeae*). It is a tall dioecious palm, reaching 30 m in height, native to North Africa and China. The wild form is not

Fig. 29. Date palm with ripe fruit

known. It yields excellent-quality fruits containing up to 70 per cent sugar, 2.5 per cent oil and 2 per cent protein.

Date culture was begun in the U.S.S.R. with the planting of suckers from Iran and seeds from Iran and California in Kisil Atrek, Turkmenia. The first crop was harvested in 1940. The maximum per tree yield achieved at Kisil Atrek is 102 kg with fruit clusters weighing up to 19 kg. The fruits are of good quality, ripening in October (Fig. 29).

The date palm is relatively winter-hardy, with the leaves killed at —10°C and the tree at —13.6°C. The date is easy of culture, drought-resistant (surviving long spells without being watered), tolerant of saline soil and stands well to dust storms and hot winds. Altogether it is a highly valuable plant and should be more extensively cultivated in Turkmenia.

The strawberry tree. A subtropical evergreen fruit and ornamental tree between 5 and 12 m high. The fruits are strawberry-like, up to 1.5 cm in diameter, of agreeable flavour, fragrant, used fresh and preserved. It grows in Georgia, Azerbaijan and on the Black Sea coast of the Crimea. Besides this species, *Arbutus Andrachne* L. of the family *Ericaceae*, another member of *Arbutus*, *A. Unedo* L., is found in these regions. The latter is very similar but has almost twice as big fruits and is somewhat hardier. Both species are of sufficient interest to warrant more extensive planting in the subtropical regions of the U.S.S.R.

Citrus Fruits

This group of fruit plants includes evergreen trees and shrubs: the lemon, sweet orange, mandarin, grapefruit, shaddock, citron, lime, bitter orange, kumquat and bergamot. They are widely cultivated in countries bordering on the Mediterranean (Spain, Italy, Greece, Israel, Morocco, etc.), in South Africa, India, China, Japan, the U.S.A. and South America, particularly Brazil. In the U.S.S.R. citrus cultures are mostly in Georgia (about 99 per cent), with small areas in Azerbaijan (Lenkoran and Astari Regions) and Krasnodar Territory (Adler and Sochi Regions) and, in recent years, in Central Asia.

The citrus fruits are native to tropical and subtropical regions. They are intolerant to cold. For instance, mandarin leaves can stand up to —8°C (the tree —13°C), sweet orange leaves —7°C, and lemon leaves only about —4°C. For this reason the warmest regions and slopes are chosen for citrus culture in the Soviet subtropics and all techniques are employed to ensure normal termination of the vegetation period; the plants are frequently individually protected. Use is also made of citrus culture in trenches, glass-houses and pots.

The citrus plants are early maturing, long-lived and very productive. In Georgia mature trees of sweet orange and mandarin yield, with good care, up to 3,000 and even 6,000 fruits per tree. The sugar content of citrus fruits may reach 12 per cent in the mandarin, 9 per cent in the sweet orange, 5.5 per cent in the grapefruit and 4.4 per cent in the lemon. Their acid content is from 0.3 to 8.1 per cent, the highest being in the lemon. All of them contain vitamins A, B and C

and are valued for their medicinal properties. They are used to make juices, jams and marmalade. The unripe fruit and the peel of many citrus fruits are candied or made into glazed fruits and jam. They yield industrial oil, pectin, citric acid and essences used in the food and perfume industry. Valuable volatile oils are extracted from leaves, flowers and fruit rind. Some citrus plants yield wood valued in joinery. Citrus juice has many medicinal uses.

In the U.S.S.R. the following citrus fruits are of economic importance.

The mandarin—a small spreading tree; the leaves are large, dark-green; the flowers are small, white. The fruits are medium-sized, weighing 30-90 g, depressed globose. The peel is yellow-orange, of variable thickness, accounting for 18-38 per cent of the total weight. The pulp is orange, slightly subacid.

The sweet orange—a medium-sized tree, up to 10-11 m high, with a compact rounded head and usually spiny branches; the leaves are oblong; the flowers white. The fruits are variable in size (100-300 g), subglobose or oval. The peel is of orange, reddish or yellow colour, smooth, variable in thickness (from 1.8 to 2 or even 6 mm), accounting for 17 to 42 per cent of the total weight. The pulp is orange-yellow or yellow-red; the flavour is subacid, sometimes sour or sweet.

The lemon—a small-sized tree, 3-5 m high, with thorns. The leaves are oval-oblong, light-green. The fruits are medium-sized, weighing 90-120 g, oval to globose, with an apical papilla. The peel is light-yellow, thin, sometimes thick, often more or less rough. The pulp is whitish, very acid. The seeds are few. Four to five lemon varieties are cultivated in the Soviet subtropics.

The grapefruit—a dwarf tree (when on trifoliate orange stock) with a shrub-like growth. It bears its fruits not singly, as the other citrus trees, but in clusters of 4-12 fruits, to which fact it owes its name. The fruits are large to very large (from 150 to 600 g), flattened spheroid to globose. The peel is lemon-yellow or light-greenish-yellow, smooth, thick (7-15 mm, sometimes up to 21 mm), and accounts for 40-60 per cent of the total weight. The pulp is greyish-yellow, juicy, of peculiar bitter taste, possessing high dietetic value and vitamin-content. The seeds are many (from 20 to 50) or none at all.

Of certain interest are also some other citrus species, viz., the *shaddock*, *citron* and *kumquat*.

The genus of the citrus fruits, *Citrus* L., belongs to the family *Rutaceae* and includes 16 species. These are trees and shrubs, with a tendency to early bearing, sometimes thorny, almost all of them evergreen and ether-bearing. Their fruit is used fresh and in the confectionary industry. They grow wild in Asia, in India and Indonesia, and in Australia. Listed below are some of the citrus species.

The lemon (*C. Limonia* (L.) Osbeck). The wild form is not known. A small tree up to 3-5 m high, with short thorns and persistent leaves, giving off when rubbed a characteristic lemon odour; fruits are usually small, very acid, yellow in colour.

The mandarin (*C. reticulata* Blanco). It seems to be native to the Fillipine islands and is widely cultivated in Italy, the U.S.A. and China, and less so in the U.S.S.R. and some other countries. It is a small tree with small, persistent leaves. The fruits are small to medium, depressed-globose, orange-yellow. The pulp is juicy and sweet; the seeds are few or none.

The sweet orange (*C. sinensis* (L.) Osbeck). It is native to China. A medium-sized tree, up to 10 m high, usually with spines, and bearing persistent, medium-sized leaves. The fruits are large, subglobose or oval, yellow or orange.

The Seville or *bitter orange*, or *sour orange* (U.S.) (*C. aurantium* L.). A tree up to 10 m in height, with spines on young growths. It is native to South-East Asia. The wild form is not known. It is used as an alternative rootstock for the citrus varieties.

The grapefruit (*C. paradisi* Macf.). It is a large tree, up to 10 m in height, with slender spines. The flowers are white, very large, borne singly or in clusters. The fruits are large, depressed-globose, light-lemon or orange.

The citron (*C. Medica* L.). The tree bears large fruits with thick rind (2-4 cm), rich in pectin. Fruits are used by the confectionary and canning industry; rind is candied or preserved. It is cultivated mostly in Georgia (Abkhazia and Ajaria Territories).

The shaddock or *pomelo* (*C. grandis* Osbeck). A large round-topped tree with spiny branches. Leaves and flowers are large. Fruits are very large (up to 17 cm in diameter), globose or pyriform; pulp is subacid, slightly bitter. The wild form is not known. It is cultivated in China, Japan, India, etc. It was introduced to the Black Sea coast of the Caucasus

in the early 20th century and several forms and varieties are now in cultivation in this area, e.g., Shaddock Dessertny, Shaddock Grushevidny.

The lime (*C. aurantifolia* Swing.). A small spiny tree bearing small, oval fruit, 3-6.5 cm in diameter, with 10 segments, greenish-yellow when ripe, very acid, rich in vitamin C. The lime is perhaps the most sensitive to cold of any known citrus species. It is found in all tropical countries, often in a semi-wild condition. Limes are too thin-skinned to keep well and are mostly used to make bottled lime juice. A few lime varieties are cultivated, on a very small scale, in Georgia.

C. tamurana Tan. A tree of medium size, with thorny branches. Leaves are medium-sized; flowers are small; fruits are large (up to 144 g), containing up to 6 per cent sugar and 3 per cent acid. Fruits are used both fresh and processed. It was introduced from Japan in 1936 and is now cultivated in Ajaria.

The Bergamot orange (*C. bergamia* Risso and Poir.). A medium-sized tree (3-4 m), unarmed. Flowers are medium-sized, white. Fruits are medium-sized, round or pyriform; pulp is very acid. It is mainly grown for the oil of bergamot extracted from the rind and used in the perfume industry. It is little cultivated in the U.S.S.R.

The kumquat, of the genus Fortunella, includes several species, such as *F. margarita* Swing. (oval kumquat) and *F. japonica* Thunb. (round kumquat). These are evergreen shrubs or small trees. Fruits are small (up to 2-3.3 cm), edible with the skin, of a sweet agreeable flavour, also used for preserving. They grow and bear well on the Black Sea coast of the Caucasus.

The trifoliate orange (*Poncirus trifoliata* (L.) Raf.) belongs to a different genus of the *Rutaceae*. A thickly branched, spiny deciduous shrub. The fruit is small, globular, many-seeded, of yellow colour, inedible. It is a hardy species and makes a good stock for citrus fruits.

Soft Fruits

The strawberry. The strawberry is widely grown in the U.S.S.R. The plant reaches 25 to 30 cm in height, has a shallow root system (in the top 50 cm of soil) and is grown commercially for 3 to 5 years. It is valued for easy propagation, early maturity, high yield, excellent quality of fruit

which is retained when it is frozen or preserved. The berries contain 80 to 90 per cent moisture, 5 to 9 per cent sugar, 0.3 to 1.5 per cent acid and 0.71 per cent ash. Plants start bearing in the second year after planting. Yields average 3 to 8 tons per hectare, though much higher yields are recorded, e.g., in 1961 in the Timiryazev Agricultural Academy in Moscow where 13.1 tons per hectare were cropped over a territory of 6.5 hectares.

The strawberry is cultivated all over the Soviet Union, from the Khibin Mountains in the west to the island of Sakhalin in the east, but the best yields are obtained in central Russia, in the Ukraine and Northern Caucasus.

The Hautbois is little cultivated in the Soviet Union because this plant is dioecious and there are no large-fruited varieties.

The genus of the strawberry and *Hautbois*, *Fragaria*, belongs to the family *Rosaceae* and includes 45 species growing in Europe (4), Asia (15), and North and South America (26). The main species are given below.

The wild or *Alpine strawberry* (*F. vesca* L.). A perennial herb with a scaly subterranean rootstock, leaves palmately three-foliate and sharp-toothed, all from the rootstock, leafless scapes and rooting runners on whose knots new plants are formed. Flowers are bisexual, white; fruits, small, fragrant and tasty. Grows in the wild in forests all over Europe.

The scarlet, or *Virginian strawberry* (*F. virginiana* Mill.) and the Chilian strawberry (*F. chiloensis* Ehrh.), both common wild strawberries in North America, have somewhat larger flowers than *F. vesca*.

The common garden strawberry (*F. grandiflora* Ehrh.) is the cultivated form. It is held that it has originated from a cross between the Virginian and Chilean strawberries because the characters of both are easily detected in it. At present over 2,000 varieties of the garden strawberry are known, with large fruit weighing up to 30-70 g.

The Hautbois (*F. elatior* Ehrh.). A dioecious plant with musky berries. Native to Europe, including the European part of the U.S.S.R.

The other species, such as *F. orientalis* Los. and *F. peapetala* Kydh., present interest as potential material for breeding work.

It is commonly believed that the "everbearing" varieties have originated from *F. vesca* L.

The raspberry is a relatively common cultivated soft fruit in the U.S.S.R. Raspberry plants have perennial roots and erect or nearly erect canes from 1 to 2.5 m long. Plantations may be used for 15 to 20 years. It is valued for easy propagation (by the use of suckers which spring from the underground parts), early bearing (in the second year after planting), high yields (6-10 tons per hectare) and excellent quality of fruit, which can be frozen and preserved. The berries are purple- or golden-coloured, from 2 to 5.5 g in weight, and contain 4 to 8 per cent sugar and 0.9 to 1.3 per cent acid.

The dewberry is closely related to the raspberry, but is less hardy and little cultivated in the U.S.S.R. It has pendulous creeping thorny canes, 0.5 to 1.5 m long. The berries are black, from 3 to 12 g in weight, of a mildly acid pleasant flavour, and contain up to 6-75 per cent sugar and nearly 1.09 per cent acid. They are used fresh and for making juices and preserves.

Raspberries and *dewberries* belong to the genus *Rubus*, of the *Rosaceae* family which also includes the blackberry, the cloudberry and other species. All of them are low, mostly woody plants, usually producing canes; some are herbaceous perennials. Altogether there are about 450 *Rubus* species, including about 120 in the raspberry or *Idaebatus* subgenus and over 200 in the dewberry and blackberry or *Eubatus* subgenus. In the U.S.S.R. where *Rubus* grow from the Arctic circle down to the southern borderline S. V. Yuzepchuk recognizes 42 natural species of raspberry and dewberry, of which but a few are cultivated. Below are listed the more important species of *Rubus*.

The raspberry, or *European raspberry* (U. S.) (*R. idaeus* L.). A low woody plant with mostly erect canes and a perennial rootstock which annualy gives rise to suckers. The flowers are bisexual, the fruits red, less often yellow. Occurs in the wild all over Europe and in the north-west of Asia. It has originated a number of cultivated varieties.

The red raspberry (*R. strigosus* Michx.). Much like *R. idaeus*, but distinguished by fewer suckers and more slender bearing canes which are brown. Widely spread in the forests of North America, also in Asia. It gave rise to several cultivated varieties.

The black-cap raspberry, or *thimbleberry* (U. S.) (*R. occidentalis* L.). A bush with a deeper root system and more pendulous canes than *R. idaeus*. Propagated by seed and by

canes rooting at the tips; produces no suckers. The fruits are black. It grows in the wild in North America.

The purple-cane raspberry (*R. neglectus* Peck). A perennial bush propagated by seed, suckers or "tips". Widely spread in North America, also occurs in Europe. L. H. Bailey considers that it is really a large and variable race of hybrid between *R. strigosus* and *R. occidentalis.*

The dewberry (*R. caesius* L.). A low bush with prickly canes forming dense growths. A very polymorphous species. The fruits vary in size and are used fresh and preserved. Over 30 species of dewberry are recognized in the U.S.S.R., with fruit of varying quality. There are also numerous North-American species which, like their European relatives, gave rise to many cultivated varieties.

R. arcticus L. A perennial woody plant with erect branches reaching 30 cm in height. The fruits are small, dark-red, resembling those of the dewberry, subacid with a pleasant pineapple fragrance; are used fresh and preserved. There are no cultivated varieties. It inhabits lowlands in the northern and central zones of the European part of the U.S.S.R., in the Urals, the Caucasus, Siberia and the Far East.

The cloudberry or bakeapple-berry (*R. Chamaemorus* L.). A perennial almost creeping plant from 5 to 40 cm high; dioecious. The fruits are small, resembling those of the raspberry, bright yellow, fragrant, used fresh or processed. It grows in the wild on the bogs in the north of the European part of the U.S.S.R., in the Arctic, Siberia and the Far East.

R. nessensis W. Hall. A bush or semibush, height up to 1.5 m, with prickly canes. Leaves with 5-7 leaflets. The fruits are black or purple, used fresh and preserved. Widely spread on wet soils of the middle belt of the Russian Federation, in North Caucasus, and South Siberia.

The currants are relatively widespread in the U.S.S.R. Three main kinds are distinguished—black, the most popular of the three, red and white. Currants are perennial shrubs with several year-old and older wood branches, 1 to 2 m high, and possessing a relatively shallow root system. Plants live from 15 to 20 years. Fruit buds are formed on second year's growth. The currants are valued for early maturity, high yields (4 to 11.5 tons per hectare), and good-quality fruit (particularly the red currants) which are used both fresh and processed. The black currant is rich in vitamin C and contains 4 to 10 per cent sugar and 2.9 to 3.7 per cent acid.

The currants belong to the genus *Ribes*, the family *Saxifragaceae*. This genus includes all the various kinds of the black, red and white currants. All of them are perennial shrubs. They number about 110 species, of which only 7 are known to be cultivated. They grow as far north as the Arctic circle and as far south as the mountainous areas on the Soviet southern border. Of the three, the black currant requires most moisture and the red currant the least. The following are the most important species.

The black currant (*R. nigrum* L.). This species is the parent of most of the cultivated black currant varieties.

The garden currant (*R. vulgare* Lam.) and the *red currant* (*R. rubrum* L.) were used as parent forms for the cultivated varieties of the red and white currants.

The golden or *Missourri currant* (*R. aureum* Pursh). In view of its vigorous growth and drought-resistance this species is recommended as a shelter-belt plant. It is also used as rootstock for currants and gooseberries grown from a stem or leg. Propagation is by seeds and by cuttings. Working with its seedlings I. V. Michurin obtained his Crandall's Seedling variety.

The gooseberry is widely cultivated in the U.S.S.R., particularly in Gorky, Moscow and Leningrad Regions. Gooseberries are perennial shrubs, reaching 1.5 or more m in height. They start bearing in the second or third year after planting. Their plantations are used for 15 to 25 years. Gooseberries are valued for easy propagation (by layers and softwood cuttings), early maturity, high yields (10-20 or more tons per hectare), high-quality fruit which is used both fresh and processed. The fruits are large reaching 57.9 g in weight, of varied colour, and contain 8.5 to 10.5 per cent sugar and 1.45 to 1.9 per cent acid.

The genus of the gooseberries is *Grossularia* Lindl. of the family *Saxifragaceae*.

The genus includes 52 species, all of them low shrubs, growing in Europe, Asia, North Africa and North America. The following are the more important species.

The gooseberry (*Gr. reclinata* Mill.) has fruit of yellowish-green colour. It is the parent of most of the large-fruited cultivated varieties.

The far-eastern gooseberry (*Gr. Burejinensis* Berger) has excellent-quality fruit used for making preserves, syrups and wine.

Several species, such as *Gr. acicularis* Spach; *Gr. hirtella Spach*; *Gr. Cynosbati* Mill., are of interest for use in breeding work with gooseberries.

The cranberry, cowberry and related species. These soft fruits belong to the genera *Oxycoccus* (cranberry) and *Vaccinium* (the rest) of the family *Vacciniaceae.* In the U.S.S.R. none of them have been brought under cultivation so far, though the fruit of these species are gathered in large quantities by the population of the northern areas. In the U.S.A. a large-fruited cranberry is grown on peat bogs while blueberry culture has become quite an important industry in recent years.

The cranberry or *small cranberry* (U.S.) (*Ox. palustris* Pers.). Slender creeping plants. The fruits are globular or oblong, 0.3 to 2 cm in diameter, red, juicy, sour, and contain 2.84 per cent sugar, 2.45 per cent citric acid and 0.22 per cent ash; are used for jams, etc. The cranberry grows over vast areas across the entire north of both the European and Asian parts of the U.S.S.R., where in some places as much as 1.5 tons per hectare are gathered.

The cowberry or *whimberry*, *mountain cranberry* or *foxberry* (U.S.) (V. *vitis-idaea* L.). A low evergreen shrub, up to 30 cm in height. The flowers are pinkish-white. The fruits are red, up to 1 cm in diameter, globular, acid and somewhat astringent, are used both fresh and processed. Yields are up to 300 kg per hectare. The cowberry grows in the coniferous and mixed forests of the middle (Byelorussia) and northern zones of the U.S.S.R., as well as on the islands in the Arctic Ocean, favouring the vicinity of shrubs, and also on peaty bogs.

The whortleberry, *bilberry* or *blueberry* (*V. Myrtillus* L.). A low perennial shrub, 15 to 45 cm high. The flowers are pink. The fruits are globular, up to 1 cm across, juicy, black with a bloom, mildly subacid, used preserved. The berries contain up to 8 per cent sugar, 0.8 to 1.45 per cent acid and up to 0.75 per cent pectin. It grows in the mixed and coniferous forests in the U.S.S.R.

The bog bilberry (*V. uliginosum* L.). A low spreading perennial shrub, 0.25 to 1.5 m high. The flowers are pinkish-white. The berries are oblong, up to 2 cm across, bluish-black with a bloom, sour-sweet and contain up to 6.8 per cent sugar, 1.75 per cent acid and 0.65 per cent pectin. Yields may be as high as 0.5 tons per hectare. The berries are used

both fresh and processed. The bog bilberry grows mostly in the north on peat bogs, as well as in coniferous forests.

The low blueberry (V. *pennsylvanicum* Lam.). A dwarf shrub, 15-37 cm high, with branches glabrous or hairy northward. Leaves are oblong-lanceolate or elliptical, shining and green on both sides. Flowers are greenish white, on short pedicels. Berries are large, bluish-black with a bloom, sweet. It is native to North America and is increasingly cultivated in the eastern states.

The actinidia. The genus *Actinidia* Lindl. belongs to the family *Actinidiaceae* (Van Tiegh.). All actinidia plants are climbing shrubs. The fruit is a soft berry, with numerous small seeds, very rich in vitamin C. The genus includes 25 species, all native to East Asia. Of these, three species occur in the Soviet Far East.

I. V. Michurin introduced actinidia culture in the U.S.S.R. (Fig. 30). The actinidia has long been in cultivation in China where there are some very good varieties. The following are the more important species.

A. arguta (Sieb. and Zucc.) Miq. The fruit is subglobose, greenish-yellow, about 2.5 cm long, sweet.

A. kolomikta Max. The fruit is oblong-ovoid, blue, juicy and very sweet.

The schizandra. Belongs to the family *Magnoliaceae*, the genus *Schizandra*, the species *Sch. chinensis* Baill. These are dioecious woody canes 1 to 2 cm thick, climbing to the height of 10 to 15 m. The bark on old vines is dark-brown and yellow on the young. Leaves are broadly oval or ovate, dark-green and shining above. Flowers are large, white or pinkish, fragrant. Fruits are in racemes, 20 to 30 in each, small, globular, scarlet, sour, contain up to 12.6 per cent malic and citric acids, and are used as preserved food and for medicinal purposes.

The schizandra grows wild in the U.S.S.R. in areas along the Amur, in the Far East and on the island of Sakhalin. In recent years it has been introduced into the middle belt of the U.S.S.R.

The mulberry. A member of the genus *Morus* L., of the family *Moraceae*, which includes 18 species, either trees or shrubs. Being drought-resistant they are highly valuable for steppe afforestation and for planting in orchards for their edible fruit. The following are the more important species.

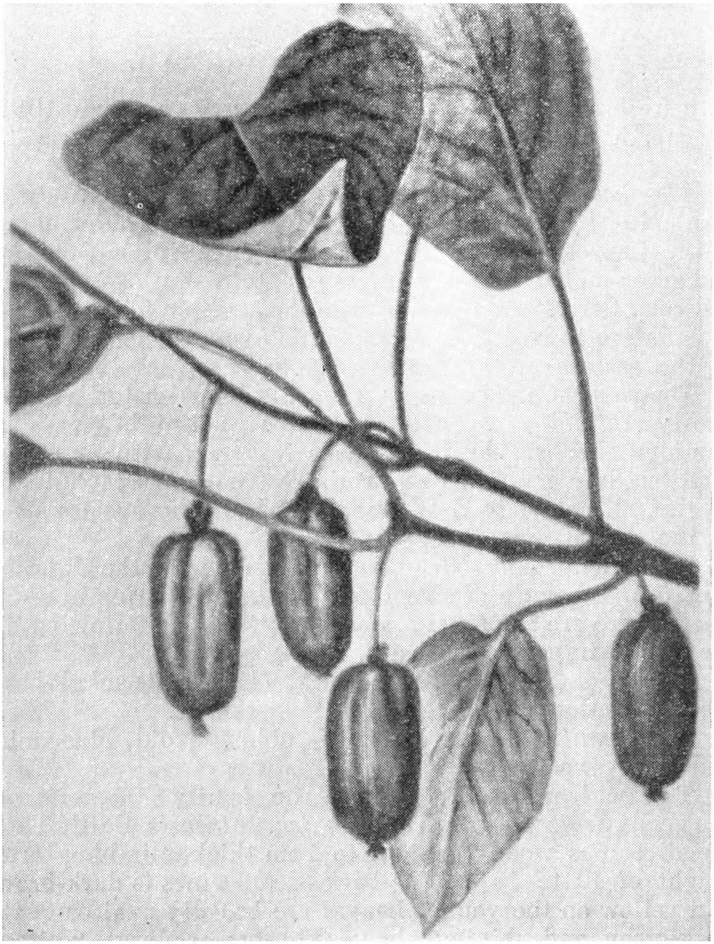


Fig. 30. Clara Zetkin actinidia

The black mulberry (*M. nigra* L.). Large trees reaching 15 m in height. The fruit is large and of good quality.

The white mulberry (*M. alba* L.). It is grown principally for its leaves which are used for feeding silkworms, and also for the edible fruit. Propagation is mostly by seeds.

Miscellaneous Fruit Plants

Certain fruit plants, which are not part of any of the groups described above, present interest either for planting in orchards, forests or shelter-belts, or as naturally growing supplies of fruit. They include:

The Cornelian cherry belongs to the genus *Cornus* of the family *Cornaceae* including about 50 species, of which 10 are known in the U.S.S.R. Only one species—*C. mas.* L.—is cultivated. It is a shrub, up to 3 m high, or a small tree, up to 8 m high. The wood, being hard and close-grained, is used in joinery. The fruit is a juicy drupe, red or yellow, sour and tart. The large-fruited varieties are grown for their fruits which are rather sweet when fully ripe and can be eaten fresh and dried, or used for making jams and wine.

The Cornelian cherry grows in the wild in the Caucasus, Moldavia and the Ukraine, where there are several large-fruited varieties containing 6.9 to 9.1 per cent sugar and 1.7 to 2.9 per cent malic acid. Cornelian cherry culture is still in its infancy.

The honeysuckle. Belongs to the genus *Lonicera* of the family *Caprifoliaceae*; the two species concerned are *L. caerulea* L. and *L. edulis* L. They are hardy much-branched shrubs, up to 1.5 m high, with small oval to oblong leaves. The flowers are small, yellow. The fruits are rather large, up to 2 cm long, oblong, black, with a bloom, sour, edible and containing 4.4 per cent sugar and about 1 per cent citric acid; they ripen in June and are used processed.

It grows in the wild in the Soviet Far East and in the taiga along the Ussuri and Amur rivers. I. V. Michurin was the first to recommend it for cultivation. It is also used as a highly attractive ornamental shrub (Fig. 31).

The guelder-rose or European cranberry-bush (U.S.) (*Viburnum Opulus* L.) belongs, like the last, to the family *Caprifoliaceae*. A shrub reaching 4 m in height. The fruits are red, subglobose to oval, 7 to 13 mm long and occur in racemes, The fruits have a bitterness which disappears after the first frosts or after steaming under cover; they are used as admixture to bread dough, and for making pies and jellies. The juice is used for making marmalade and jellied fruit.

The guelder-rose can be grown in shelter belts and as an ornamental shrub.

The oleaster (*Eleagnus angustifolia* L.) belongs to the family *Eleagnaceae*. A shrub, sometimes spiny, or small tree, up to 6-8 m high. The leaves are small, oblong-lanceolate, silvery beneath. The flowers are highly fragrant. It is an excellent honey plant and an annual heavy cropper. The fruits are small, starchy, rather sweet and can be used either fresh or cooked.

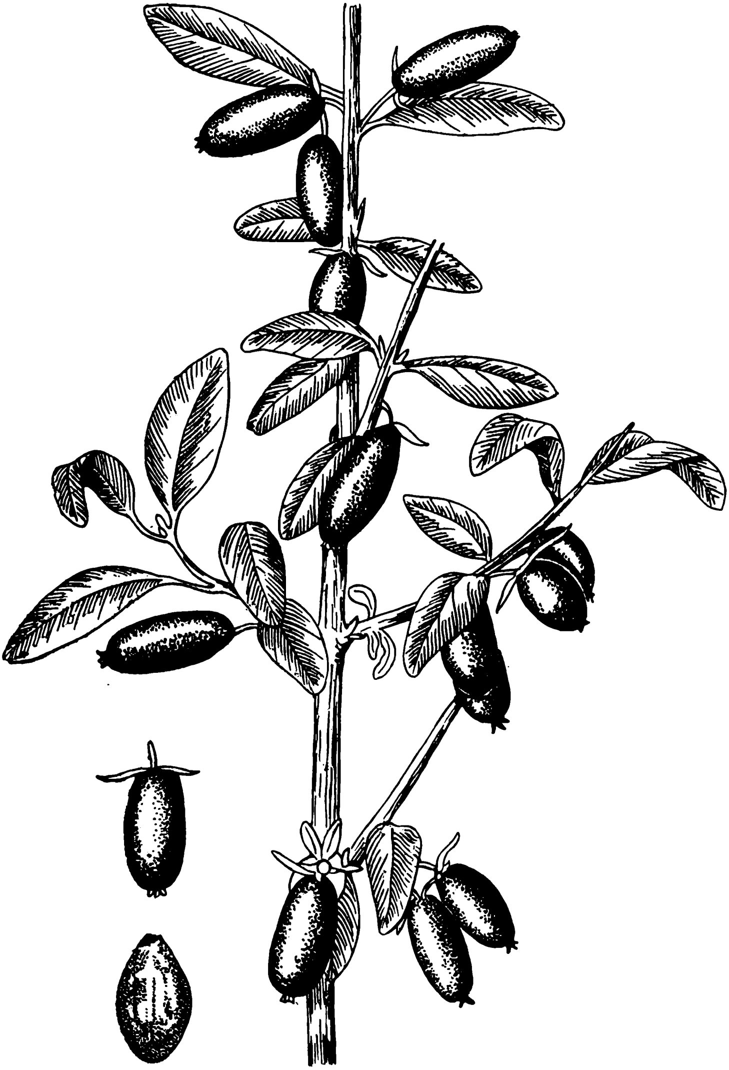


Fig. 31. Black honeysuckle

The oleaster can be grown in shelter belts and hedges, and as an ornamental plant. It is very drought-resistant. Propagation is by seeds, suckers, hard-wood or soft cuttings and also root cuttings. Oleasters are widely grown in Armenia and Central Asian republics.

Another species—*E. orientalis* L.—is very much similar, except it has larger fruit, up to 2.5 cm long. It is a common sight in Central Asia, together with *E. edulis*, a small shrub, up to 1.5-2 m high, bearing dark-red edible fruits resembling Cornelian cherries.

The barberry (*Berberis vulgaris* L.) belongs to the family *Berberidaceae*. A medium-sized spiny ornamental shrub. It usually grows singly in forests, river valleys and on slopes. The fruits are small, in clusters, yellowish-scarlet, subacid, of good quality, containing 4 to 6 per cent sugar, up to 5 or more per cent malic acid and vitamin C. The berries are used either fresh or as a dressing to some dishes as well as for making preserves, jellies, juices, etc.

The sea buckthorn (*Hippophäe rhamnoides* L.) belongs to the family *Eleagnaceae*. A shrub, up to 1.5 m high, or a tree, up to 10 or more m, with spiny branches. A dioecious plant; starts bearing on the 3rd or 4th year after planting. The fruits are up to 1 cm across, subglobose or ovoid, yellow or red, variable in flavour from outright acid to sweet with pineapple fragrance. They contain 2 to 12.6 per cent sugar, 1.1 to 3.15 per cent acid, 1 to 10 per cent oil and a number of vitamins. They are used either fresh or processed and are known to possess medicinal properties.

The sea buckthorn grows in Siberia, Central Asia, in the Caucasus and in some areas in the European part of the U.S.S.R. At present it is being adopted for cultivation in view of the value of its fruits.

Of great interest are also such forest trees as the *beech* and the *cedar* which grow in the U.S.S.R. over vast areas and yield thousands of tons of edible nuts. The kernel of these nuts is rich in oil and protein, and it is eaten raw. An oil used for cooking and other purposes is pressed from it.

Fruit Plants of the U.S.S.R.

For easy reference all the fruit plants growing in the U.S.S.R., either naturally or in cultivation, are listed in Table 4 given below.

Table 4

Fruit Plants of the U.S.S.R.

Group	Kind	Botanical name	
		family	genus
Pome fruits	Apple	Rosaceae	Malus
	Pear	ditto	Pyrus
	Quince	ditto	Cydonia
	Mountain ash	ditto	Sorbus
	Service tree	ditto	ditto
	Black chokeberry	ditto	Aronia
	Medlar	ditto	Mespilus
	Hawthorn*	ditto	Crataegus
	Service berry*	ditto	Amelanchier
Stone fruits	Sour cherry	ditto	Cerasus
	Sweet cherry	ditto	ditto
	Bird cherry*	ditto	Padus
	Plum	ditto	Prunus
	Blackthorn	ditto	ditto
	Apricot	ditto	Armeniaca
	Peach	ditto	Persica
Nuts	Walnut	Juglandaceae	Juglans
	Pecan	ditto	Carya
	Filbert	Betulaceae	Corylus
	Almond	Rosaceae	Amygdalus
	Pistachio	Anacardiaceae	Pistacia
Subtropical fruits	Sweet chestnut	Fagaceae	Castanea
	Olive	Oleaceae	Olea
	Persimmon	Ebenaceae	Diospyros
	Fig	Moraceae	Ficus
	Pomegranate	Punicaceae	Punica
	Feijoa	Myrtaceae	Feijoa
	Avocado	Lauraceae	Persea
	Loquat	Rosaceae	Eriobotrya
	Cherry laurel*	ditto	Laurocerasus
	Papaw	Anonaceae	Asimina
	Jujube	Rhamnaceae	Zizyphus
	Japanese raisin tree	ditto	Hovenia
	Date palm	Palmae	Phoenix
	Strawberry tree*	Ericaceae	Arbutus

(*continued*)

Group	Kind	Botanical name	
		family	genus
Citrus fruits	Mandarin	Rutaceae	Citrus
	Sweet orange	ditto	ditto
	Bitter orange	ditto	ditto
	Lemon	ditto	ditto
	Grapefruit	ditto	ditto
	Kumquat	ditto	Fortunella
	Citron	ditto	Citrus
	Shaddock	ditto	ditto
	Lime	ditto	ditto
	C. tamurana	ditto	ditto
	Bergamot orange	ditto	ditto
	Trifoliate orange*	ditto	Poncirus
Soft fruits	Strawberry	Rosaceae	Fragaria
	Hautbois	ditto	ditto
	Raspberry	ditto	Rubus
	Dewberry	ditto	ditto
	Cloudberry*	ditto	ditto
	Currants	Saxifragaceae	Ribes
	Gooseberry	ditto	Grossularia
	Cranberry*	Vacciniaceae	Oxycoccus
	Cowberry*	ditto	Vaccinium
	Whortleberry*	ditto	ditto
	Bog bilberry*	ditto	ditto
	Low blueberry	ditto	ditto
	Actinidia	Actinidiaceae	Actinidia
	Schizandra	Magnoliaceae	Schizandra
	Mulberry	Moraceae	Morus
Miscellaneous	Cornelian cherry	Cornaceae	Cornus
	Honeysuckle*	Caprifoliaceae	Lonicera
	Guelder-rose*	ditto	Viburnum
	Oleaster*	Eleagnaceae	Eleagnus
	Sea buckthorn*	ditto	Hippophae
	Barberry*	Berberidaceae	Berberis
	Beech*	Fagaceae	Fagus
	Cedar*	Pinaceae	Pinus

* Found in the wild only

CHAPTER THREE

•

THEORY OF GROWTH AND DEVELOPMENT OF FRUIT PLANTS

Definition. The growth of all plants, whether annual or perennial, and this includes fruit plants, goes on all their life, with the resultant increase in bulk, and cell and organ differentiation. Simultaneously, or with certain time-lags, qualitative changes occur in plants, which are considered to be manifestations of the development of plants.

According to D. A. Sabinin (1955), growth is formation of new structural elements in the organism or, according to a fuller definition by P. A. Genkel (1962), growth is the increase in weight and volume due to the formation of new structural elements in the organism. The development of plants is that process of qualitative changes in them which is indispensable for the transition of a plant from a reproductive cell (zygote, spore, organism) to the single or repeated formation of new reproductive cells. As can be seen from the above, "growth and development are not identical phenomena. But they are very closely linked together" (P. A. Genkel, 1962).

Theory of Individual Development of Fruit Plants

Charles Darwin was the first to formulate the theory of development of the organic world. According to him, the nature of all plants and animals—their structural and physiological peculiarities—is the result of an age-long interaction between an organism, and other organisms and environmental conditions surrounding it. Charles Darwin considered individual life within the framework of the evolution of living nature as a whole.

K. A. Timiryazev developed Darwin's concept about the connection between ontogeny, i.e., the development of

the single organism, and phylogeny, i.e., the history of the development of its predecessors. He also supported the idea of purposeful regulation of changes in plants, which he maintained was possible due to the different requirements of plants for environmental conditions.

I. V. Michurin further developed Darwin's theory of the evolution of plant life and Timiryazev's ideas about the growth and development of fruit plants. He based his numerous researches, which he began in 1905, on the indisputable fact of the age-long evolution of plant organisms, and on the genetic make-up developed by their ancestors in specific environmental conditions and passed over to them. He discovered that seedlings in early stages of their development bear certain resemblance to the wild-growing forms from which they originated. This points at the close link between the individual development of a seedling (ontogeny) and the age-long development of the parental forms from which it originated (phylogeny).

He believed that individual development is conditioned by the entire preceding development of a given species, that it is a dialectico-materialistic process passing qualitatively through different stages.

I. V. Michurin ascribed a great significance to the influence of environmental conditions. He considered that at certain periods in the development of the organism its heredity, along with the whole organism, may undergo certain changes under the influence of environmental conditions, that organism and environment form in fact a unity. This is why, he said, new hybrid plants should be given all the appropriate soil, nutrition, lighting and other conditions, such as will enable them to develop their cultural characters to the full.

I. V. Michurin established five periods, or stages, in the individual development of fruit plants: embryonic, juvenile, productive (usually divided by him into the early mature and the mature periods) and senile, which all greatly differ among themselves morphologically and physiologically. A young seedling passes through two stages: embryonic and juvenile.

The embryonic period in the development of a plant begins with the formation of a zygote, i.e., a fertilized cell, as a result of the fusion of a male gamete (antherozoid) with its female counterpart (ovum), which later develops into a seed on the mother plant. In this initial period of its develop-

ment a plant is characterized by a maximum plasticity and response to changes in environmental conditions.

I. V. Michurin points out that the quality of a hybrid seedling, i.e., of a future variety, may be influenced by the rootstock on which the parental plant was budded or grafted, by the position in the tree crown of the fruit in which the new organism is being developed, by natural and other factors of the environment.

The juvenile period in the development of a plant starts with the appearance of first real leaves and continues for the first three to five years of fruit bearing. The length of this period varies according to different species and also depends upon environmental conditions, plant care included. For instance, strawberries have the shortest juvenile period, from one to two years, while apples and pears have the longest—from 8 to 20 years.

In the juvenile period, especially at the beginning of it, just as in the embryonic period, hybrid seedlings possess high plasticity and a tendency to accommodate themselves to the new conditions of life. Experience in plant breeding shows that some of the characters acquired by a young hybrid plant under the influence of environmental conditions in which it is placed in the embryonic and juvenile periods may become fixed to be passed on to its offspring.

In the juvenile period of a seedling, particularly in the early stage of its development, the appearance of thorns, small and thin downy leaves and other characters usually typical of its wild progenitors may be observed.

I. V. Michurin established that tissues along the stem are genetically heterogenous. He wrote that if we cut a mature, bearing hybrid tree at the root collar the shoots arising from the stump would have a wild appearance and in their subsequent development would repeat all the morphological changes through which the seedling had passed after germination.

Consequently, whereas the branches of a mature seedling plant are of the cultivated type the dormant buds on its root collar may produce shoots which for some years will possess many of the characters of their wild progenitors. That is why differences may be observed in plants raised from cuttings taken from different parts of a seedling particularly before it has started bearing. The plants raised from cuttings taken from the top part of a seedling where cultivat-

ed varietal characters have become permanent always exhibit cultivated characters. On the other hand, cuttings coming from the bottom portion of a seedling or its branch may have to pass, after rooting, through the unfinished stages of development, gradually acquiring the characters of the cultivated variety.

The difference in characteristics of branches is also manifested in the fact that cuttings taken from different parts of the same tree or from trees of different ages have a different rooting ability. The older the tree and the higher up is the branch from which the cutting is taken, the poorer it takes root.

As a seedling grows it manifests the characters of the cultivated variety which was used as parent.

"Every plant", wrote I. V. Michurin in 1905, "has the faculty of altering its constitution, adapting itself in the early stages of its life to new environmental conditions. But this faculty manifests itself in greatest degree in the first few days after germination and then diminishes; and after one, two, three, or occasionally five years of fruiting, it gradually disappears. Thereafter the newly-obtained variety becomes so resistant to change in the direction of greater hardiness that any acclimatization is practically out of question".

I. V. Michurin (1905) was the first plant biologist to elucidate the peculiarities of the embryonic and juvenile period in the development of fruit plants.

F. Kobel (1930) described peculiar growth forms in pear seedlings and arrived at a conclusion that seedlings of fruit plants, just like conifers (Beissner, 1888), pass through a juvenile development phase. He also supposed that certain phenomena, so far unexplained, in fruit growing should be attributed to the fact of fruit trees passing through a juvenile phase.

F. Passecker (1940) established marked differences in the shape of apricot and peach leaves in seedlings as compared to the leaves of the grafted or budded cultivated varieties. In his work he cites cases of remarkable difference in seedlings, such as a bigger angle of lateral branches and a greater development of bark, xylem and phloem (in thickness and number of fibres) from the mature forms.

As a result of researches conducted at a Swiss experimental station R. Fritzsche (1948) defined the juvenile form as the first stage of development of a plant grown out of a seed,

during which certain differences in habit, anatomical structure and chemical composition as well as in physiological behaviour may be observed between it and the fully grown plants, i.e., the mature form.

I. M. Kovtun (1954) found that thorns may appear on growths arising from low-lying, phasically young tissues on pear trees. Some workers have established that plants graft better in the juvenile period, while in the reproductive period they graft poorly or not at all.

Qualitative differences in tissues are also manifested in the root system of fruit plants. Fruit growers and foresters have long found that the roots of seedlings are much more viable than the roots springing on cuttings or layers, which are usually taken from older organisms.

There are indications in horticultural literature that plants springing from roots at different distances from the trunk are qualitatively different.

P. G. Sidorenko (1954) obtained experimental data showing that (a) parts of the root situated nearer to the root collar, i.e., formed in the earlier stages of ontogeny, root better than those situated in the periphery of the root system; (b) plants grown from root cuttings and root sprouts taken nearer to the root collar have a "wilder" appearance than those grown from cuttings and sprouts taken nearer to the periphery of the root system; they differ in water- and chlorophyll-content and in some other characters.

There is, however, some contradicting evidence. Investigations conducted in Michurinsk by G. A. Kursakov (1959) showed that all growths from a rootstock had exactly the same morphological characters no matter what part of the root system the cutting had been taken from, which means that apple roots did not pass through the stages of development typical of the top parts of the tree. Evidently more research into the problem is needed.

Taking advantage of the greater adaptability of plants in the first two periods of their development to the changing environmental conditions and believing that inherited characters are not passed over in a ready form but are subjected to possible gradual changes, I. V. Michurin elaborated a number of methods of producing and conditioning of hybrid seedlings: selection of parental pairs for hybridization, etc. The efficiency of these methods has been proved by numerous new varieties originated through their use.

I. V. Michurin found that after three to five years' bearing the seedling enters the *productive period*, or the *period of maturity*. This period is characterized by a marked decrease in the plasticity and adaptability of the hybrid organism to changed conditions and, consequently, by a relative stability of its characters. Any modifications of these characters are usually no longer deep or significant. During this period the plant attains the maximum spread of both its top and root systems. The length of the period depends in large measure on the plant's genetic make-up, and on natural and cultural conditions.

In order to obtain plants uniform in size, fruit quality and other characters the fruit growers propagate them by vegetative means making use of seedlings in this productive period.

It has long been observed, however, that the vegetative propagation of plants in their productive period, even of old varieties, may, though rarely, produce radical changes in them. Such changes occur in the protoplasm of the growing points of wood and fruit buds and may affect branches, leaves, flowers and fruits. They are called *bud sports* or simply sports. They are heritable and may be fixed by vegetative propagation. Such vegetative alterations gave rise to numerous varieties such as 600-gram Antonovka and Red Korobovka apples and Williams' bon Crétien pear.

I. V. Michurin pointed out that branches with fruit buds taken from old varieties may, sometimes, produce, on rooting, early-bearing dwarf-type trees. Qualitative difference in tissues may be also observed during the productive period within the whole tree (ordinary branches, water-sprouts, etc.) and within one single branch (buds in the bottom, middle and top parts of the branch).

N. I. Turovtsev (1960) found that the branches of apples (Papirovka, Reinette Bergamotte, etc.) which had developed from adventitious buds had bigger-sized and more vigorous leaves than those developed from the main and axial buds.

Despite the long standing popularity of certain varieties I. V. Michurin emphasized the fact of their changing value depending on area of planting and mode of management, and insisted on systematic local adaptation of such varieties.

The term variety in horticulture usually denotes a vegetatively propagated form of a fruit plant possessing more or less distinct characters (shape of tree, size, shape and

colouring of fruit, size of crop, longevity, winter-resistance, etc.).

Consequently, only a careful selection of grafting and budding material for use in vegetative propagation can ensure uniform top-quality planting material.

The end of the third period in the life of a plant is marked by a decrease in growth vigour and the dying off of the tips of branches as it enters the fourth period, *the period of senescense*, followed by the death of the plant.

Contemporary with I. V. Michurin, but mostly much later, extensive research was done into dependence of the rhythms of plant ontogeny on the rhythms of environmental changes, particularly in connection with the phenomena of vernalization and photoperiodism, into the causes of morphological and physiological modifications in plant organs, and the physiological significance of hormones, vitamins and other physiologically active substances. These research works have enabled plant scientists to advance a number of theories and hypotheses such as the carbohydrate-nitrogen and other biochemical theories of flowering, and the hormone theory of plant growth, etc. (M. Kh. Chailakhyan, 1958).

Certain research has been done into the phases of development of fruit plants. For instance, V. I. Piskaryov (1938) advanced an idea that the seeds of fruit plants pass through the vernalization phase while they are stratified. In 1954 A. P. Rodionov corroborated this idea in his experiments on peach seed germination. However, the indicated similarity between vernalization and stratification is still a matter of further experimentation.

Theory of Cyclic Ageing and Rejuvenation of Plants

In 1940 N. P. Krenke put forward a theory of cyclic ageing and rejuvenation of plants, or a theory of growth cyclicity, which incorporated extensive experimental data gathered by him and his associates and some evidence in horticultural literature. The author of the theory distinguishes between the age of individual parts and their total age in relation to that of the plant. *The own age of a part of a plant* (branch, bud, leaf, etc.) is the time from the moment of its formation till the moment of observation.

The total age of the same part is the time composed of its own age plus the age of the parent tree up to the formation of the corresponding part. Thus the month-old leaves on young trees are younger than the month-old leaves on old trees though the conditions of growth may be exactly the same.

N. P. Krenke introduced two more concepts, those of initial and extant potentials in the development of plants. *The initial potential* is the normal average life expectancy of a plant. *The extant potential* is the difference between the entire initial potential and the part of it spent by the given moment in the life of a part of a plant.

All plants and animals grow old and die. Ageing just as the entire normal average life expectancy of organisms, i.e., the initial potential of viability of genetically different organisms and their parts, is a character brought about through evolution and basically expressing the qualitative difference between their proteins and the entire metabolism.

Biological ageing is the common character of all organisms and of each of their cells, the actual life span of an individual organism and of its parts being subjected to different conditions of ontogenic development.

By timely use of sound management (cultivation, manuring, irrigation, pruning, etc.) a large measure of regulation of the processes of ageing and rejuvenation can be achieved. The longevity of the whole plant as well as its parts may be greatly increased just as its spread and crop. Thus, for instance, nitrogenous fertilizers retard the process of ageing while phosphates speed it up.

All changes in all organisms are essentially age changes, i.e., they are all connected in some way with the age of the organism. These changes may not coincide entirely with the calender age of the organism.

The process of ageing goes on in the entire organism and in its parts, uninterruptedly but unevenly. The process of general individual ageing, i.e., lowering of the potential of viability, is attended by uneven cyclic rejuvenation. Rejuvenation consists in the formation of young structures or elements and a delay in ageing of the existing ones but it does not mean a return to the past. Every living cell ages biologically and dies, the process being tied up with the age of the cell. The appearing daughter cells are tempo-

rarily rejuvenated compared to the mother cell. The author of the theory sees in this "the first indication of the cyclic recurrence".

Certain differences in the rates of ageing have been established between the resting and dividing cells of plants. The ageing is slower in the resting meristematic cells, e.g., the cells of the growing points of dormant and adventitious buds, as well as the cells of the upper parts of seed embryos.

It appears that the early-bearing apple varieties compared with the late-bearing ones have closer spaced leaves, i.e., their internodes are shorter and they are more branchy. This theory makes it possible to explain the ageing and degeneration of a variety propagated vegetatively for a long time, certain rejuvenation following budding, the extension growth of shoots (water-sprouts) on the lowest orders of branching which are always younger and more vigorous than on higher orders, and some other phenomena.

The theory of cyclicity of ageing is largely based on morphological and physiological processes and reduces the development of the entire complex organism to ageing and rejuvenation, the nature of which it does not fully reveal. "While disagreeing with N. P. Krenke's opinion about the rejuvenation of an organism in the process of ontogeny, one should say with all fairness that changes somewhat resembling those observed in the cases of real rejuvenation do occur in the organism in the course of its life. To describe such changes one could suggest the term 'renewal', reserving rejuvenation for those cases when a new organism appears and the cycle of development begins afresh". (P. A. Genkel, 1962).

Yet it is to N. P. Krenke's credit that he has pioneered the study of these most important problems. And though certain elements in his theory have not been fully worked out and are open for debate, it helps to reveal certain regularities in plant ontogeny connected with the age of the organism.

Apart from its biological importance the theory of age cyclicity is of theoretical and practical importance for plant breeding (the determination of earliness of a future variety at the age of one or two years), and for better propagation, shaping and pruning of plants.

Age Periods of Fruit Trees

The first mention found in literature of age periods in the life of fruit trees was made by V. Poenicke (1905) who distinguished three periods: (1) the period of development and growth, (2) the period of attaining maturity, formation of seed and fruit, (3) the period of maturity, during which the organs gradually collapse.

Later a division in 5 age periods appeared in literature (P. G. Schitt, 1937). In his recent textbook "*Fruit trees*" M. Coutanceau (1962) also describes 5 periods: (1) the juvenile period—the development of the tree until first blooming, (2) the period of active growth and the beginning of bearing, (3) the adult period or the period of full bearing, (4) the period of weakening, but qualitatively valuable bearing and the cessation of growth and (5) the period of senescence.

On the basis of Darwin's theory of evolution and the works of K. A. Timiryazev, I. V. Michurin and others, and also the extensive data collected in the course of large-scale surveys of the fruit areas of the U.S.S.R. P. G. Schitt (1936) proposed to divide the life of arborescent fruit plants at first in 5 and later (1940) in 9 age periods (Fig. 32). The following is his justification for the division and the characteristics of each age group.

When passing through the periods of its individual development, from its appearance from seed or seedling (after budding or grafting) to its death due to old age, a fruit tree will reflect different stages of growth and development characteristic of the different stages of its life cycle. Throughout its entire individual life the tree develops vegetative and reproductive organs, this process being accompanied by the dying away of separate sections of its head. The resultant changes vary from tree to tree of the same variety depending on age. They are significant and visual so that it is easy to break the cycle of individual development of a tree into age periods based on these changes.

Despite the considerable variation in tree longevity, all fruit forms exhibit the same sequence of the above-mentioned nine periods of development. This shows that no matter what natural and cultural conditions are, all trees reflect in their development the corresponding changes connected with their age.

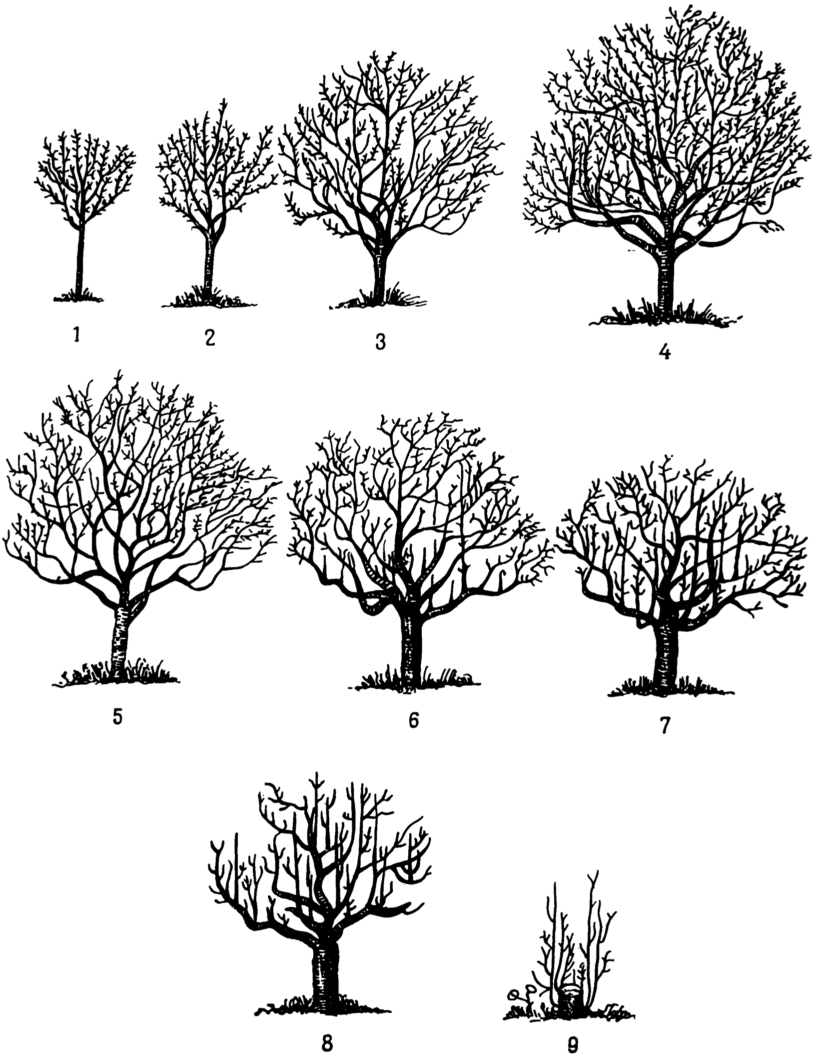


Fig. 32. Diagram of the life cycle of fruit trees after Schitt (figures refer to age periods)

It follows from the above that tree care aimed at creating optimum conditions should be carried out with due account of the changes occurring in a tree as part of its life cycle and not of calendar dates.

1. **The period of growth.** This period comprises the development of a young plant from seed, or from grafting or budding, to first crop. For apples and pears this period extends from five to eight or more years, for peaches from two to three years and for the other stone fruits from four to five years. This period is characterized by ever increasing growth of main branches and main roots. There is vigorous shoot growth, particularly on the periphery of the head with a gradual slow-down inside it, and the trees increase their growing seasons, which tends to retard the maturing of wood.

Cultural requirements. In this period it is essential: (a) to form the main framework of branches; (b) to encourage formation of more fruiting wood and preparation of the tree for first bearing; (c) to create conditions for optimum growth and development of the tree conforming with its biological peculiarities and the climatic conditions; (d) to protect trees from freezing injury, particularly those with an excessive period of shoot growth, and from pests and diseases.

2. **The period of growth and bearing.** This period comprises the development of the tree from first bearing to regular bearing. The fruit reaches maximum development and commercial quality. Vegetative growth is still on the increase. However, this is mostly manifested in the formation of numerous relatively short limbs of the higher orders of branching with a constant weakening of extension growth of the central axils, and in the formation of an increasing amount of fruiting wood. In this period, particularly in its early part, there is also a tendency to longer growing seasons, which exposes plants to the danger of injury from freezing.

Cultural requirements: (a) further shaping of the tree; (b) stimulation of the formation of fruiting wood on the main branches and its correct spacing in the head of the tree; (c) slight thinning out of the shaded provisional main branches within the head; (d) tree care, and tree and crop protection against pests, diseases and freezing injury.

3. **The period of bearing and growth.** This period comprises the development of fruit trees from regular bearing to maximum bearing in the given conditions. It is characterized by a progressive increase in the amount of fruiting wood and, together with it, of crops. This is accompanied by a decrease in the formation of vegetative parts of the head, their shortening and transformation to fruiting wood. When pruning is neglected the oldest fruiting wood inside the head of the tree begins to die off. Crops continue to increase in this period given adequate tree care, but the tendency to alternate bearing is already setting in.

Cultural requirements: (a) the final shaping of the tree of the given variety in the given environmental conditions is based on biological and commercial considerations with a view to maintain a sound balance between the assimilatory apparatus and the absorbing root system; (b) the systematic thinning out of the head of the tree by removing heavily shaded branches and inducing the appearance of new fruiting wood to replace the old one on the remaining branches; (c) judicious clipping of main branches poorly oriented in the head with a view to fruiting wood renewal. Routine tree care (soil management, watering, fertilizing, top dressing, and pest and disease control).

4. **The period of bearing.** In this period the tree yields maximum crops (for the pome fruits from 15-20 to 40 years). There is hardly any growth of main branches or none at all. The growing points usually produce only shortened growths, which leads to a large-scale formation of fruiting branches and to branching on the already existing fruiting wood. Simultaneously there is a large-scale dying off mostly of short fruiting branches inside the head, and sometimes near its periphery. An earlier start of growth and an earlier termination of the growing season are observed. Crops are heavy but the commercial quality of fruit is on the decline. Fruits are becoming smaller. There is excessive ovary drop, considerable tree exhaustion, very marked biennial bearing and poor resistance to adverse conditions.

Cultural requirements: (a) creation of most favourable cultural conditions for trees (manuring, watering, etc.); (b) clipping of main branches throughout the head of the tree; (c) preparation for and carrying out of tree rejuvenation and (d) control of the size of crop by

pruning and thinning out of branches, flowers and ovaries.

5. **The period of bearing and withering away.** This period is marked by the same characteristics as Period 4 but in an advanced stage, viz., by further decrease in fruiting wood formation, progressive dying off of old spur systems, decrease in size and quality of fruit with size of crop still not diminishing and an early termination of the growing season.

Cultural requirements: (a) same as in Period 4 with the only difference that thinning out and cutting back of main branches is intensified; (b) rejuvenation of old spur systems and (c) tree care is intensified, particularly regarding treatment of wounds from cutting and freezing, as well as soil management.

6. **The period of withering away, bearing and growth.** This period is characterized by further ebbing of life activity of trees, starting with the dying off of small limbs and ending with the dying off of main branches in the head of the tree. There is a decrease in bearing and in tree spread, and increase in upward growth of water-shoots from the dormant buds at the base of the main branches. Digging out of root systems of such trees also reveals the dying off of individual scaffold roots and the appearance of new roots usually closer to the trunk.

Cultural requirements: (a) generally the same as for Period 5; (b) tree rejuvenation by means of forming water-sprouts into main branches and (c) improvement in tree care and soil management.

7. **The period of withering away, growth and bearing.** This period is characterized by an increase in the dying off of fruiting branches and the withering away of branches as well as by the appearance of water sprouts and a sharp drop in bearing.

Cultural requirements: (a) the same as for Period 6; (b) clipping old main branches to the extent where water-sprouts have arisen and the formation of the latter into new main branches; (c) taking account of the lengthening of the growing season of water-sprout branches with a view to their protection against freezing injury.

8. **The period of withering away and growth.** This period is characterized by the dying off of the bigger main branches. There is a sharp derangement in growth correlation in the tree.

9. **The period of growth.** The head and trunk die off while numerous growths appear at the base.

The last two periods have a purely theoretical significance being at the end of one life cycle and the beginning of a new life cycle of a tree arising out of stump growths. Fruit plantations in these two periods have no commercial value and are grubbed.

An understanding of the described cycle of individual development of fruit trees and its division into a number of growth periods has a great theoretical and practical significance because it helps to elaborate and carry out tree care tailored to the peculiar requirements of each period. Correct feeding and pruning may keep trees in Period 3 and 4 longer, thus increasing maximum bearing time. Besides, it helps to reveal the cyclic character of growth and development as well as the replacement of vegetative and reproductive (fruiting) branches in the heads of trees.

CHAPTER FOUR

OBJECTIVE LAWS GOVERNING THE GROWTH AND FORMATION OF ROOT SYSTEM AND AERIAL PORTION OF PLANTS

Root System

The role of roots in the life of fruit plants. The root system does not only supply the plant with water and mineral substances, store reserve nutrients and anchor it in the subsoil, as was thought for a long time; it also performs a number of other important functions. Experimental work carried out by P. S. Kossovich (1897) and D. N. Pryanishnikov (1899, 1913) revealed that plants obtain their nitrogenous food in the form of ammonia and nitrates which are equally assimilable in the conditions of optimum reaction and carbohydrate level. Reduction of nitrates to ammonia starts when they are still in the root system.

The resultant two kinds of ammonia nitrogen, both toxic, are not stored up in the plant, but are used—with sine qua non that respiration, or carbohydrate oxidation, takes part in the process—to build up amino-acids and amides, particularly asparagine and glutamine, which are harmless organic compounds of nitrogen.

Subsequently, root nutrition and the composition of root excretion and what is known as bleeding sap were studied in Russia by A. G. Doyarenko (1909), I. S. Shulov (1913), E. F. Votchal (1916) and others. E. F. Votchal discovered amylase and certain other enzymes in the bleeding sap of trees. Later I. E. Bykov (1929), also studying bleeding sap, arrived at the conclusion that the substances which are taken up from the soil by the root system are combined in the root system itself, accumulating there temporarily in the form of some unknown compounds. This means that the root system takes a more active part in plant nutrition than it was held before.

N. G. Potapov (1936) showed by many years of research that a considerable percentage of nitrogen found in bleed-

ing sap is in the form of organic compounds, including amides. It can be said therefore that the cells in the zone of absorbtion of the root system serve as the arena for one of the most important processes of secondary synthesis established earlier by D. N. Pryanishnikov in his classical works on nitrogen metabolism. Subsequently Soviet scientists obtained other convincing proof of the active role of the root system in nitrogen metabolism. Thus A. A. Shmuk, A. I. Smirnov and G. S. Ilyin (1941, 1948) found that the leaves of a tobacco plant that was grafted on a tomato plant contained no nicotine whereas the leaves of a cutting taken from the tobacco scion revealed on rooting increasing quantities of nicotine. Conversely, when a tomato plant was grafted on tobacco the tomato leaves contained up to 4 per cent nicotine.

This experiment showed that nicotine, an alkaloid, is synthesised solely in the roots and once more confirmed that the roots participate in the synthesis of organic substances in plants.

D. A. Sabinin (1955) considered that "the root system is the seat of the processes—specific for each given species—of transformation of inorganic nitrogen compounds absorbed by roots into organic compounds, often of high physiological activity". He discovered that "the energy liberated during the processes of transformation of organic compounds which the assimilating organs supply to the root systems is used for the reaction of the formation of certain physiologically active substances, i.e., vegetative hormones".

Nitrogen metabolism has also been studied in tree and soft fruits. Findings of W. Thomas (1927), S. H. Eckerson (1931), M. A. Blake (1932), G. T. Nightingale (1934), O. W. Davidson and I. W. Shive (1934), W. E. Loomis (1935), C. E. Williams (1939), L. F. Badjer, I. R. Magness and L. O. Rogeimbal (1943), and others can be summed up in the following way:

(1) in apple trees the active roots are mainly responsible for the initial stages of the synthesis of organic nitrogen;

(2) in peach trees reduction of nitrates is carried out almost entirely in the roots;

(3) no analysis has revealed any noticeable quantity of inorganic nitrogen in such plants as apples, elders and poplars in any tissue above ground;

(4) protein synthesis is carried out in the active roots of one-year-old apple seedlings placed in jars with sand and water and supplied with nitrogen; there is no accumulation of protein in the other organs and its concentration is considerably higher than in the roots of plants grown in a culture solution lacking nitrogen;

(5) as the temperature rises to 21.1 °C most of the newly synthesised amino-acids and asparagine move up from the active roots to the buds which blossom at a higher temperature;

(6) in peach trees the uptake of nitrogen by the roots occurs at temperatures above freezing point, but the absorbed nitrogen does not move beyond ground level at temperatures below +7.2 °C;

(7) there is a noticeable uptake of nitrogen in the form of nitrates and ammonium salts and its conversion into organic forms in the roots of apple trees in the period of their rest at low temperatures from 0° to 0.6 °C.

Many new facts elucidating the role played by the root system have been established over the recent years by Soviet and foreign workers employing both conventional and modern methods such as the tracer technique.

The root system of *Taraxacum hybernum*, a rubber-producing plant, is capable to produce rubber from the photosynthetic products coming downwards from the leaves (A. A. Prokofyev, 1945). Resin and rubber synthesis in the root system may be based on the use of certain unspecific products of photosynthesis flowing downwards from the leaves (L. P. Zhdanova, 1954).

A number of amino-acids are formed in the roots and then transported upwards to the leaves (A. L. Kursanov, 1954). A. L. Kursanov and his associates found that the roots take up certain amounts of carbonic acid and carbonates from the soil solution and incorporate them in the organic substances they synthesise. V. A. Chesnokov (1956) established that the roots absorb much less CO_2 than they excrete. A. L. Kursanov believes that the CO_2 taken up by roots only constitutes a few per cent of the CO_2 taken up by leaves.

I. I. Kolosov and S. F. Ukhina (1954) showed by their experiments in sterile culture based on the use of the tracer and chromotographic techniques that the isotope of phosphorus, P^{32}, absorbed by the roots is incorporated into nu-

cleoproteids and lipoids while nitrogen obtained from the soil solution as the NO_3-ion is reduced to NH_3 and used to form amines, amides and certain other organic compounds.

It has been discovered that the root system influences the photosynthetic apparatus (B. A. Rubin and V. F. Germanova, 1956), in that it participates in the regulation of the oxidation-reduction regime in the leaves. Any weakening of this function due to some inactivation of the root system results in a sharp drop in the tension of the oxidation processes in the leaves and arrests their physiological functions (L. A. Ivanov, 1953).

D. A. Sabinin (1949) emphasised that there is no direct relationship between the amount of water a plant transpires and the amount of salts it absorbs from the soil solution. There is an ion exchange between the roots and the colloidal particles of the soil affected through the intercellular solution. E. I. Ratner (1950) and A. V. Peterburgsky (1953, 1954) confirmed this by showing that exchange in plants is affected with the aid of the H^+ and HCO_3-ions.

Growing roots in culture solutions showed that provided nutrient salts and sugars, e.g., sucrose (G. D. Lvov, 1950), are readily available, the roots are able to synthesise proteins, nucleoproteids and hormones necessary for the formation of new meristems. Such roots branch readily and grow mostly in length, and very slightly in girth. Their initial meristem alone is active (A. M. Pechenitsina, 1951). It can be assumed that isolated roots are unable to provide all the organic compounds necessary for their normal development.

The remarkable ability of the root system to increase in length and to branch, the latter ability being over one-thousand-fold more developed in the roots than in the top system, has been pointed out. "As is known, the meristematic cells, just as the cells of embryonic tissues of plants, are rich in the nucleic acids, approaching the cells of microorganisms in their high level of nucleoproteids." (D. A. Sabinin, 1949).

The sugars which move from the leaves down to the roots are eventually oxidised there to pyruvic and other organic acids. These organic acids interact with the ammonium salts absorbed by the roots to produce substantial quantities of amino-acids and other organic compounds which then are rapidly transported upwards into the leaves (A. L. Kursanov, 1960).

It is a well-established fact now that the subsoil is rich in microorganisms. E. N. Mishustin (1956) discovered that the total number of microorganisms in 1 g of soil runs into hundreds and even thousands of millions. The ploughing layer of sierozems in Central-Asian republics contains about 7 tons of live microbes per hectare. Due to the constant process of multiplication and dying off the mass of microbes is completely renewed 2 or 3 times in one month, i.e., 8 to 12 times per growing season, in the middle belt of the U.S.S.R. Thus during the growing season dozens of tons of substances rich in nucleoproteids changes in the top layer of every hectare of land.

The rhizosphere is very important in the plant-soil relationship. The root excretions enrich the soil round the roots with numerous organic and mineral compounds (organic acids, amino-acids, phosphates, etc.) and encourage bacterial and fungal activity (N. A. Krasilnikov, 1952). There is a sharp drop in the numbers of bacteria and fungi outside the rhizosphere. Microorganisms produce substances which stimulate plant growth (V. V. Bernard, E. Kh. Rempe et E. A. Voronkova, 1956). Of great importance is the cycle of organic substances which is dependent on the dying off of bacteria, fungi, protozoa, insects, worms, animals, on root excretions (M. Busgen, 1907; A. I. Akhromeiko, 1936), and on "root shedding" (term introduced by the author) or dying off of the roots.

M. V. Lomonosov (1711-1765), P. A. Kostychev (1877-1931) and other Russian scientists pointed out that the humus content of the soil depends on the root systems of plants. N. A. Kachinsky (1925) said: "The roots provide the overall background for the distribution of humus in the soil while the water-soluble organic substances washed out of the top parts of the plant only make up the foreground, their bulk being apparently fixed in the top layer of the soil."

I. V. Tyurin (1937), A. F. Tyulin (1955), A. Ya. Orlov (1955) and others consider that the roots are the principal source of organic substances in the soil. The accumulation of the humus substance, microorganisms and soil animals is conditioned by the activity of roots. For instance, investigations carried out by A. F. Tyulin showed that oak roots constitute one per cent of the weight of soil in the upper horizons.

The dying off and renewal of root systems of seedlings entails the dying off of thousands and those of mature plants of hundreds of thousands of roots, whose weight totals several tons per year (V. A. Kolesnikov, 1924, 1930). According to calculations done by A. Ya. Orlov (1955), the weight of absorbing roots dying off in one year under a forest of 25-year-old firs equals two tons per hectare. Roots die off continuously during the growing season and particularly in two great waves—in the early spring and in the autumn.

Intensive dying off of roots in these two periods explains in the author's opinion the heightened life activity of microorganisms in early spring and autumn as observed by N. N. Khudyakov (1955) who wrote: "It is a well-known fact that in spring when the soil is only just starting to warm up the microorganisms increase in number while in summer, in what would seem to be the optimum conditions of temperature, moisture and food, there is a manifold decrease; in the autumn again, as it gradually becomes colder, microorganisms increase in number."

The significance of the dead roots in the life of the soil and the plants is enormous, yet it is still not taken sufficient account of in the investigations of both the horticulturists and soil scientists.

It has been rightly said (K. A. Timiryazev, 1884, G. D. Lvov, 1950) that the root system moves in the direction of food and water though the plant itself stays rooted in its place. Readily available nutrients flow to the roots while the feeding roots themselves have to seek the less mobile nutrients. To provide the plant with sufficient food and moisture the roots have to spread wide and grow numerous feeding roots and root-hairs.

It will be seen from the above that the significance of roots in plant life is great and varied. The roots of all plants discharge the following main functions:

1. The uptake of water and dissolved mineral substances from the soil and the formation of amides, amino-acids, proteins, lipoids, nucleoproteids, hormones and other organic substances.

2. The excretion into the soil of organic substances, such as sugars and organic acids, and inorganic compounds of phosphorus, potassium, etc., which contribute to the dissolution of mineral substances and the development of microorganisms, the latter in their turn helping to create con-

ditions necessary for plant nutrition in the active root zone.

3. The active influence on the solid phase of the soil and the transition into solution of part of the adsorbed ions, as well as the assimilation of carbonic acid from the soil and the provision of the branch system with the products of its conversion. It should be noted that the root system satisfies the vital needs of the leaves in water and products of its own manufacture while on the other hand it is supplied with energy and structural material in the form of carbohydrates produced by the leaves. Root systems regulate the oxidation-reduction processes in the leaves (S. M. Ivanov, 1953).

4. The symbiotic interaction with mycorrhiza, both living inside the cells (endotrophic) and on the root surface (ectotrophic), as well as with the rhizospheric complex of organisms.

5. Accumulation and storage of food reserves.

6. The penetration of roots as a result of the dying off and renewal process into new, unused layers of soil containing moisture and nutrients, and the deposition in the soil of organic substances formed of dead roots.

7. Propagation of certain species, such as sweet cherry, plum and raspberry, by root suckers.

8. Anchoring the plant in the soil.

It should be added that, as found in recent years, the speed of translocation of nutrients and water in plants is very high. Assimilated products move downwards to the roots at a speed of 0.7-1.5 m/h, while mineral substances move upwards at a speed of 2-4 m/h and water up to 14 m/h (A. L. Kursanov and A. Kleshnin, 1954).

Types of root growth. Three types of root growth are distinguished:

(1) growth in length of the main and the lateral roots of the higher orders, with the resultant increase in the absorbing surface of the root system;

(2) initiation of lateral roots, or new formations (branching) of the root system, which also increases its absorbing surface;

(3) growth of the roots in girth, which mainly increases their weight.

The absorbing roots develop root hairs. The length of the absorbing roots plus their root hairs is the measure of the total absorbing surface of a root system.

Branching of roots. Root branching varies with variety and species, as well as with natural conditions and management. Branching in the root system is more extensive than in the aerial portion of the plant.

Roots of seedlings. The first root that breaks from a planted seed, from its radicle, is the primary, or main root. Then the hypocotyl appears, the cotyledons start to swell and stem formation begins as the terminal bud, or plumule, breaks into vegetative growth. In this is manifested the bipolarity of a plant embryo, i.e., its ability for simultaneous development of different organs in two opposite directions.

Once the seedling has established itself, growth of the main root is rapid until it reaches 10 to 20 cm in length when it starts to ramify. The main root is termed a root of zero order, secondary roots arising from it are of the first order and so on. The seedlings of fruit trees produce up to 5-7 ramifications in one growing season with the predominance of third to fourth order roots. In the conditions of Moscow Region a year-old Chinese apple seedling may grow up to 40 thousand roots with an aggregate length of 230 m in one growing season. Compared with the Chinese apple, one-year-old seedlings of *M. sylvestris*, the Siberian apple, (*M. baccata* L.) the pear, the sour cherry and some other species develop, over the same period, considerably fewer roots with a much smaller aggregate length. Yet the total root length of a mature fruit tree runs into dozens of kilometres, while their aggregate number is of the order of several millions.

The majority of seedling roots are very short. For instance, the percentage of roots up to 5 mm long is 65 for apples and 43 for pears; while for roots 6 to 10 mm long it is 18.7 and 28 respectively. The distribution of roots according to length is shown in Table 5.

The average root length of a year-old seedling of the Siberian apple is 6 mm, the Chinese apple 7 mm, the pear and the sweet cherry from 8 to 9.5 mm, the sour cherry 8.2 mm, the Mahaleb cherry and the Chinese scholar's tree 14 mm (V. A. Kolesnikov, 1924, 1930).

The average root length, or the root coefficient, of one-year-old seedlings is a character which is relatively constant for each species despite the considerable differences in environmental conditions. This was confirmed in 1926

Table 5

Distribution of Apple Seedling Roots According to Length

Order of roots	No. of roots											
	0.1-5 mm long	5-10 mm long	10-15 mm long	15-20 mm long	20-25mm long	25-30 mm long	30-35 mm long	35-40 mm long	40-45 mm long	45-50 mm long	50-400 mm long	Total
0	—	—	—	—	—	—	—	—	—	—	1	1
1	6	14	10	7	8	5	7	—	2	4	32	95
2	715	282	204	138	142	93	66	44	37	29	96	1846
3	4153	1233	403	118	82	30	31	19	20	14	41	6144
4	2557	680	190	60	23	5	1	—	—	1	—	3517
5	470	64	—	—	—	—	—	—	—	—	—	534
6	6	—	—	—	—	—	—	—	—	—	—	6
Total number	7907	2273	807	323	254	133	105	63	59	48	170	12143
Total percentage	65.1	18.7	6.6	2.7	2.1	1.0	0.9	0.5	0.5	0.4	1.5	100.0

also for forest trees in Germany (Schreiberg and Goesselink, 1926). Further studies of dug-up and washed seedlings revealed that the root coefficients of individual root nets approximate that of their entire root system, which was particularly true for the wild-growing Siberian apple, as shown in Table 6.

It can be clearly seen from Table 6 that the average root length in any root net equalled the average root length for the entire root system even when a root net had as few as 44, 45 or 59 roots.

This analysis was carried out by the author on a considerable number of seedlings of apples, pears and other fruit and forest trees. It showed that the root coefficient was most constant for the Siberian apple and a little less so for the cultivated apple seedlings and other varieties.

The root coefficient made it possible to arrive at the length of the root system of a seedling without actually measuring it. To achieve this we only had to count all roots carefully in a washed-out seedling root system and determine the root coefficient for an average-sized net of 100 to 300 rootlets, the product of the two figures giving us a reasonably accurate total root length. This sampling technique cut the time needed by about 90 per cent and also allowed inclusion of several seedlings in each variant of the investigation.

The average root length of fruit-bearing trees is also constant though it is smaller than with seedlings, being in the case of apples about 3.5 mm. As trees grow older their average root length decreases, though very slowly (V. A. Kolesnikov, 1924, 1930, 1955).

Cyclic renewal (self-thinning) of roots. Duhamel du Monceau observed in 1760 the dying off, or "self-thinning", process in the root systems of plants, i.e., the loss of tips and the disappearance of whole rootlets and their succession by new ones, while T. A. Knight (1806) pointed out the absence of a main root in many trees. This phenomenon is easily understood when one regards the development of a plant organism as an entity of the two opposite but closely linked processes—those of formation and dying off.

The self-thinning of roots in fruit trees is of considerable theoretical and practical interest. The author established in 1924 that the dying off of tips of the main root

Table 6

Analysis of the Root System of a Siberian Apple Seedling
(Timiryazev Agricultural Academy, Moscow, July 13, 1922)

Order of root net	Order of branching													
	0		1		2		3		4		Total		Average length, mm
	Length of roots, cm	Number of roots	Length of roots, cm	Number of roots	Length of roots, cm	Number of roots	Length of roots, cm	Number of roots	Length of roots, cm	Number of roots	Length of roots, cm	Number of roots	
0	26.8	1	—	—	—	—	—	—	—	—	26.8	1	—
1	—	—	16.3	15	16.2	50	1.3	8	—	—	33.8	73	5
2	—	—	13.5	1	84.5	108	25.3	111	—	—	123.3	220	6
3	—	—	66.8	19	249.2	369	37.1	210	0.1	1	353.2	599	6
4	—	—	7.0	1	32.7	62	3.2	15	—	—	42.9	78	6
5	—	—	19.7	2	147.4	149	57.4	224	—	—	224.5	375	6
6	—	—	15.5	1	145.9	97	90.2	319	0.1	1	251.7	418	6
7	—	—	28.8	4	112.5	171	100.0	74	—	—	151.3	249	6
8	—	—	12.6	1	120.1	68	147.9	367	5.6	50	286.2	486	6
9	—	—	13.2	1	94.3	70	65.6	212	0.5	5	173.6	288	6
10	—	—	11.5	1	92.3	87	33.7	157	—	—	137.5	245	6
11	—	—	11.7	1	96.6	76	34.9	147	—	—	143.2	224	6
12	—	—	71.4	11	299.2	447	90.9	361	0.6	3	462.1	822	6
13	—	—	7.8	1	17.7	38	0.6	6	—	—	26.1	45	6
14	—	—	9.2	3	26.5	46	1.2	10	—	—	36.9	59	6
15	—	—	7.8	1	19.1	41	0.2	2	—	—	27.1	44	6
16	—	—	250.0	82	805.3	1147	5.9	907	0.4	4	1261.6	2140	6
Total	26.8	1	562.8	145	2359.5	3026	805.4	3130	7.3	64	3761.8	6366	6

occurs in the very first days of the life of apple and pear seedlings (see Tables 7 and 8).

Table 7

Percentages of Apple Roots with Dead Tips (*M. sylvestris* Mill.), 1921

Order of roots	May 25	June 9	July 6	August 10	September 14
	Number of trees				
	4	5	4	2	1
0	75.0	100.0	50.0	100.0	0
1	6.2	75.3	25.0	50.0	46.0
2	0.4	1.1	2.8	5.2	10.5
3	—	0	0.3	1.5	3.3
4	—	0	0	0.2	1.0
5	—	—	0	—	—
6	—	—	—	0	0.3
7	—	—	—	0	0
8	—	—	—	—	0

Table 8

Percentages of Roots with Dead Tips

Length of roots, mm	Apple		Pear	
	1921	1922	1921	1922
1-5	0.3	0.8	1.4	0.8
5-10	2.6	1.3	3.9	1.5
10-15	5.2	2.2	7.4	1.7
15-20	8.7	3.7	8.0	3.9
20-25	8.3	4.0	8.2	1.4
25-30	9.7	6.0	11.1	4.1
30-35	10.5	9.0	11.3	4.0
35-40	16.7	20.0	14.3	7.5

The tip of the main root in up to 80 per cent of seedlings dies off in their first two months. The dying off of tips of the roots of the first and higher orders, which is less extensive, goes on throughout the growing season. The counting of all dead tips in 26 seedlings of apple, pear and sour cherry in the course of three growing seasons showed that the percentage of dead tips in the first year of their lives

equalled 2.0 to 4.8. The number of roots counted per seedling varied from a few hundreds to tens of thousands.

As the main root and all roots of the higher orders penetrated deeper there was a gradual dying off to the base of certain lateral roots, i.e., roots of the higher order, in the very first days of their growth, and the dying off of complete nets of roots in the subsequent months, as seen in Fig. 33. Sometimes new roots or nets of roots appeared nearby to replace the dead ones.

The results of the count of the dying off of roots for pear seedlings are shown in Table 9.

Table 9

Dying off of Roots of Pear Seedlings

	1921			1922	
	July 23	August 30	September 30	May 17	June 7
Number of plants	3	4	5	3	2
Height, cm	10.5	14.4	17.0	17.0	17.0
Depth of root system	37.5	49.5	60.0	60.0	73.0
Length of first-order root, cm	30.5	616.0	776.0	755.0	865.0
Number of roots	3068	7306	8328	7669	8717
Total length, m	30.7	73.1	83.3	76.7	87.2

It can be seen from the above that by May 17, i.e., over the winter and spring, a total of 7,669 roots with an aggregate length of about 7 m had died off. By early June, when the root systems started growing, new growth began to outweigh the dying off. The same picture of new formation and the dying off of roots can be observed in all fruit plants.

During a growing season of seedling root systems revealed certain regularities:

(1) the longer the roots the more of them had dead tips;

(2) the number of roots with dead tips decreased in direct proportion to the appearance of new orders of roots, this being due to the fact that the higher the order the shorter the roots.

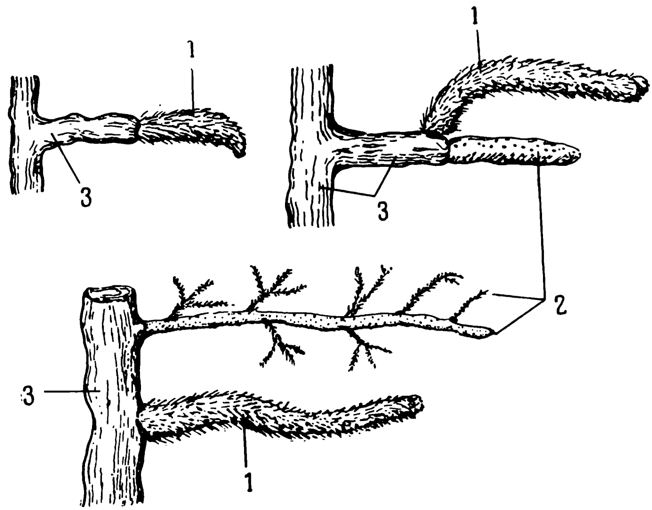


Fig. 33. Dying off and new formation of apple roots:
1—absorbing roots; *2*—dead roots; *3*—conducting roots

Throughout its life every individual plant is also annually subject to: (a) a constant and steady dying off of lateral rootlets, first on the main (zero order) root, then on the longer roots of the subsequent orders; (b) the dying off of whole root nets and their succession by new ones, i.e., denudation of the upper and thicker roots of individual, smaller roots and root nets. Even year-old seedlings may lose tens of thousands of rootlets in the course of one growing season. This is the proof of the short life of absorbing roots and root nets.

The dying off and renewal of roots in seedlings and in mature tree and soft fruits is a normal process in their life cycle just as it is, in the author's opinion, with all the other trees, shrubs and grasses. In different species the dying off of roots may be accelerated or slowed down to a different degree as a reaction to the obtaining environmental conditions.

The process of self-thinning or dying off of roots in tree and soft fruits was studied and confirmed in England for apples (W. S. Rogers, 1939) and in the U.S.S.R. for apples, sour cherries, currants and strawberries (I. A. Murom-

tsev, 1953), for gooseberries (Z. N. Voronchikhina, 1956) and again for apples (V. V. Vorontsov, 1956).

A. G. Stepanov (1959) studied the dying off of roots in apple trees at different ages. It appeared that the dying off of roots of, e.g., a 55-60-year-old tree, increased as it grew older, particularly between the 5th and 9th age periods, and the number of its live roots decreased. The dying off process spread from the stem area towards the outer boundary and from the upper horizons of the soil down to its deeper layers.

Due to the dying off and renewal process the roots of plants constantly invade fresh, unused layers of soil throughout the growing season and all their life. They spread forth from the stem in circular bands, dying off in one place and appearing in another, in search of favourable growth and fruit-bearing conditions. However, rootlets may reappear, though in fewer numbers, on older roots in the already occupied layers if soil nutrition is improved.

Formation of the root system. The growth and formation of a root system depends on root origin (seed or stem), plant or stock variety, natural conditions and management. Fruit trees are mostly obtained by budding or grafting on seedling stocks.

Their root systems develop from seed and so are younger than the rest of the plant organism; they are more viable and resistant to unfavourable environmental conditions. Usually such root systems penetrate deeper into soil than the root systems developed from parts of stems, i.e., from plant organisms in a later growth period, removed from the seed stage by one or several croppings.

Rate of root growth is different in horizontal and vertical directions and, consequently, root distribution in soil horizons is uneven. In the Moscow Region, for instance, root growth of fruit trees in 1952-1961 averaged 20-36 cm horizontally and 17-33 cm vertically; in the Crimea, 20-25 cm and 5-15 cm; in the Kuban area, 38 cm and 50-100 cm respectively. The differences are considerable and the grower should take good account of them when siting and preparing soil for an orchard and in subsequent root and soil care. The mass of roots below horizon A_0 can be increased in practically any soil, including soddy-podsolic, provided sound management is used, particularly deep ploughing with thorough cultivation and fertilizing.

Depending on natural conditions and management feeding roots may be very mobile; in one growing season, starting with early spring and finishing late in the autumn, they may grow or stop growing and die off, or be cut by cultivation tools, and then appear again in the same or new layers of soil.

Spreading steadily, the root system of a seedling, as it grows into a mature tree, penetrates vast volumes of soil with its powerful network of thick and long main roots, hundreds of thousands of rootlets and tens of millions of root hairs.

Horizontal roots of fruit trees run between 30 and 50 cm deep in the northern zone, 50 to 75 cm in the middle belt and 100 to 120 cm in the southern zone (the Kuban area). According to studies made by G. I. Gruzdev (1937) in different zones of the European part of the U.S.S.R., the main mass of roots is distributed in the humus-accumulative horizon and in the upper illuvial horizon. As seen in Fig. 34, the root mass in the accumulative horizon A is 78 per cent in the forest-steppe zone, 66 per cent in the chernozem zone, 48 per cent in the dark-chestnut soil, 33 per cent in the sierozem and 36 per cent in the soddy-podsolic soil.

In apple orchards in the middle part of the Volga area the main mass of roots is evenly distributed to the depth of 90 cm on heavy loams and to the depth of 40 cm on carbonate loamy chernozem (mainly in the humus horizon). Apple roots on alluvial soils in Georgia account for 36 per cent of root mass occuring down to the depth of 40 cm. The main mass of apple roots reaches down to 20-60 cm on Uzbek sierozems. As much as 66.9 per cent of apple roots on the meadow loamy soil in the Dniester flood-plain run in the top 60 cm, while 60 per cent of plum roots are not lower than 50 cm.

Root depth in fruit trees also depends on species and rootstock. In the Moscow Region, for instance, the main mass of horizontal roots is distributed on soddy-podsolic soil down to 75 cm in apples, 50 cm in pears, 40 cm in sour cherries and 30 cm in plums (Fig. 35) while the roots of a 16-year-old Antonovka apple tree extended to a depth of 18-30 cm on the Chinese apple, 20-35 cm on Doucin III, 25-40 cm on Antonovka seedling and 25-45 cm on *M. sylvestris* (V.A.Kolesnikov, 1955; N. Gena, 1959).

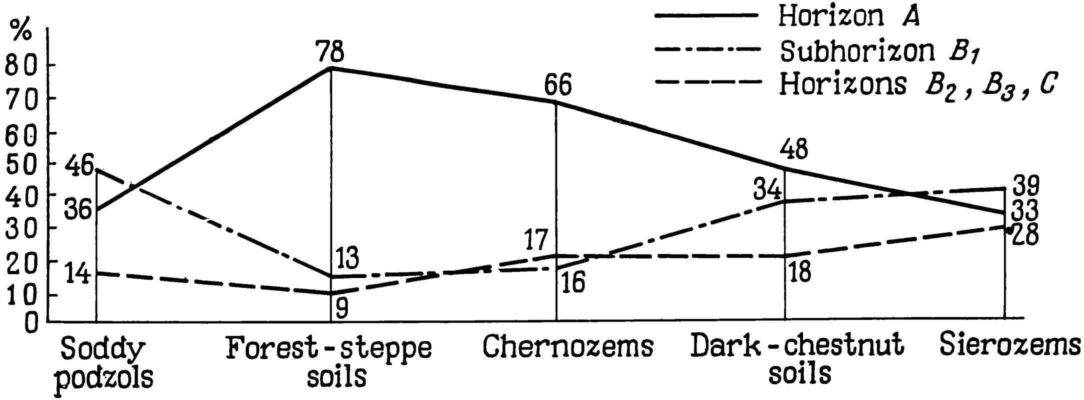


Fig. 34. Distribution of apple roots in soil horizons in different soil zones (after G. I. Gruzdev

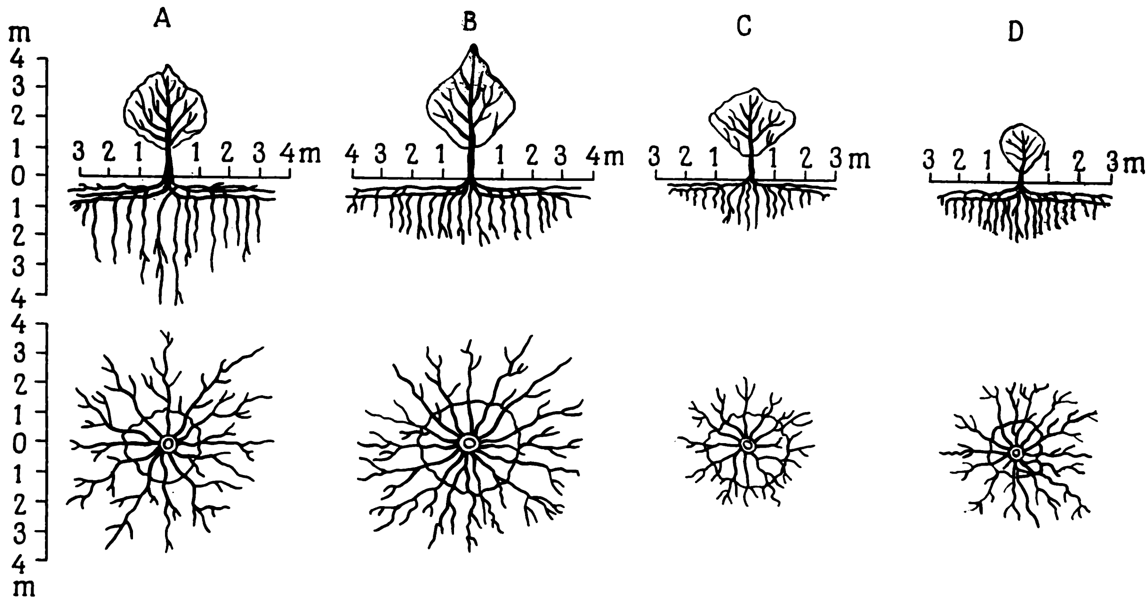


Fig. 35. Vertical and horizontal sections of the aerial portion and root system of 13-year-old fruit trees in the Timiryazev Agricultural Academy orchard in Moscow:

A—apple; *B*—pear; *C*—plum; *D*—sour cherry; circles in horizontal sections show tree spread

Root development is also influenced by relief; e.g., roots on an even 10 per cent slope tend to grow along the slope (V. Popa, 1960).

Radial root penetration of one and the same variety, under similar natural conditions and management, depends on the rootstock used. For instance, in Uzbekistan a Rosmarine blanche on Chimgan apple spread 12.5 m and on the local Chinese apple only 6 m; a pear on vigorous rootstock spread 8.7 m and on quince, only 3 m (A. A. Rybakov, 1956). In the Crimea the roots of an apple on *M. sylvestris* spread as wide as 11-14 m. In the Moscow Region 16-year-old Antonovka Obyknovennaya apples spread 2.5 m on *M. sylvestris*, 3 m on Antonovka seedling and Doucin III, 3.7 m on Chinese apple and Anis seedling, while the figure for 16-year-old pears was 2.5 m (N. Gena, 1959).

Due to the limiting factor of hard, sometimes cemented soil formations or buried horizons root systems may grow in layers. In the Kuban area (Krasnodar Region), e.g., the first layer of apple roots lay at a depth of 75-100 cm and the second, 220 cm; in grey soddy-podsolic soil in the middle part of the Volga area, at a depth of 18 and 101-140 cm respectively.

Excavations carried out by the author in the Crimean valley orchards showed that in orchards with a high water table 15-cm-deep ploughing (Fig. 36) led to removal of 60 m of roots more than 1 cm thick per 15-year-old tree, while in some other orchards even 20-cm-deep ploughing cut no such roots because all of them ran deeper.

Rootlets may be found in considerable numbers, starting from 3 to 10 cm deep, in all fruit-growing zones. It is usual for apple roots to penetrate deeper than 10-20 cm on all irrigated lands and in the north, and deeper than 30-40 cm in dry areas (Agronom state farm, Lipetsk Region).

The mass of roots distributed in the same soil horizon, i.e., at the same distance and depth from the stem, will be different in apple trees in different growth periods (after P. G. Schitt). In earlier growth periods the biggest mass of roots occurs near the extreme boundary of the system. In the middle growth periods a relative balance is achieved, i.e., the mass of roots in similar volumes of soil, say 1.2 and 5 m away from the stem, is almost equal. In the latter growth periods of trees, e.g., in the 8th period, the mass of roots is considerably greater in areas nearer to the stem.

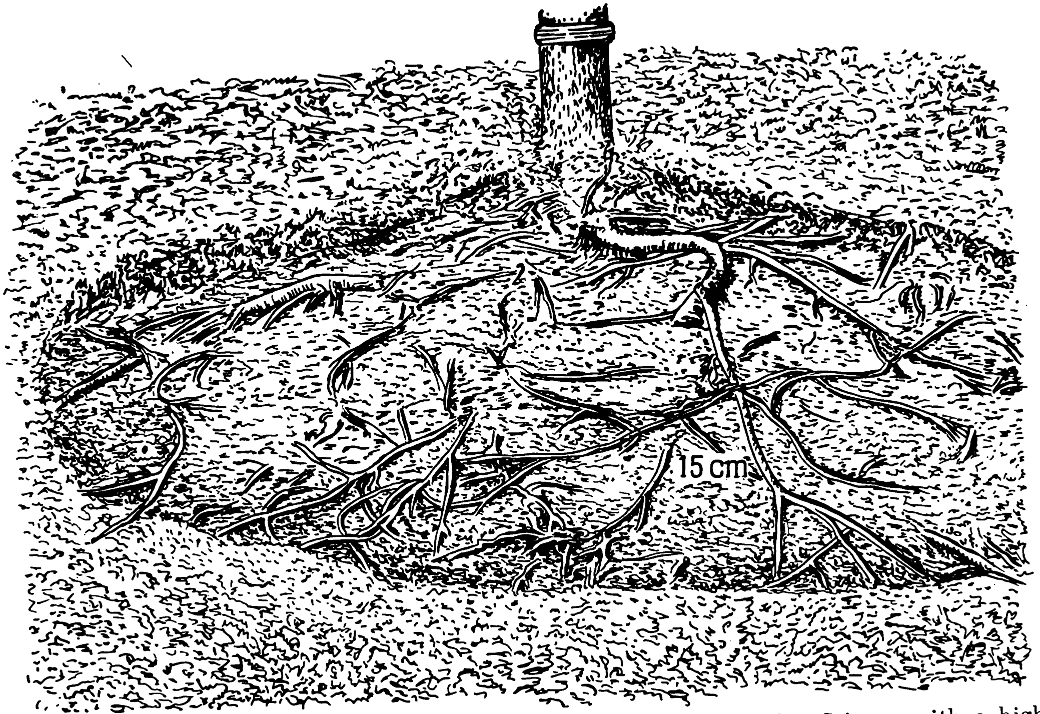


Fig. 36. Shallow distribution of apple roots (15 cm) on a site in the Crimea with a high water-table

This increase in the mass of roots, which occurs, e.g., in 30-35-year-old apple trees, is accounted for by new root formation from the root collar and at the base of the main roots. This phenomenon is similar to that of renewal top growth and coincides with the period of vigorous sucker growth. Presumably the time and vigour of development of roots will vary depending on the stock used. This process, just as the above-mentioned regularities of root growth and dying off, should be borne in mind when selecting stock and working out a soil management programme designed for fruit trees of a particular age group (A. D. Krestnikov, 1961).

It has been established by Soviet and foreign researchers that the roots of fruit trees spread further than the branches by one and a half or two times. The ratio is established during the second year in the life of a plant and is practically constant all through it—despite the differences in variety, rootstock, age, locality and management.

The roots of fruit trees do not penetrate where the soil is tightly packed, e.g., under a road. The author's studies showed (1951) that the root systems of fruit trees which have not yet cropped avoid entering a zone occupied by roots of a neighbouring tree of the same species or variety but rather slope deeper, while they may freely intermingle with the roots of a different species or variety. The latter can presumably be accounted for by the fact that different varieties have different seasonal requirements for water as well as different root growth periods. Generally speaking, root systems always gravitate where an optimum of soil conditions prevails, particularly as regards water (Fig. 37). On the other hand, the root systems of trees of the same variety may not only intermingle in fruit-bearing age but even join one another.

In the author's opinion, this may be due to the fact that the roots of a tree with little or no crop grow longer and can penetrate the root systems of sister trees with a good crop whose roots, consequently, may not grow at the time. And when roots touch they can join. Still this phenomenon needs further study.

This phenomenon was confirmed in Italy by G. Bini and P. Chrisci (1961) who found that the roots of peach trees planted 2m×2m did not intermingle among themselves, yet did so with the roots of pear trees, and by G. Bargioni

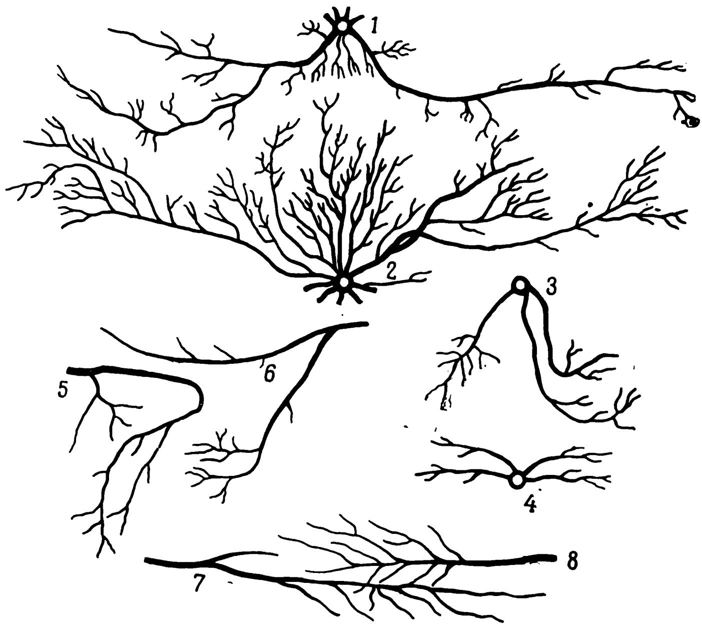


Fig. 37. Behaviour of root systems of different and same orchard species growing in close proximity:

1-2—peach trees (own-rooted); *3-4*—apple trees; *5-6* apple trees; *7*—apple tree; *8*—sweet-cherry tree

(1961) who showed that peach roots did not intermingle either in the nursery or in the orchard.

Vertical roots or "sinkers" of various fruit trees extend to 1-2 m depth in the northern zone, 2-4.5 m in the middle belt, 5-9.5 m in the southern zone (the Crimea, the Kuban area) and down to 12 m in Kazakhstan (Figs. 38 and 39). Descending roots penetrate into the soil along the paths of burrowing animals, particularly worm burrows, and natural fissures, which will be dealt with in more detail below.

Root depth is considerably influenced by the soil factor and by the individual characters of varieties and rootstocks. Apple roots in the soddy-podsolic soil of the Moscow Region descend to 3-4.5 m depth; those of pears, plums and sour cherries, to 2 m depth. On the same soil the main mass of descending roots of Antonovka Obyknovennaya apple is

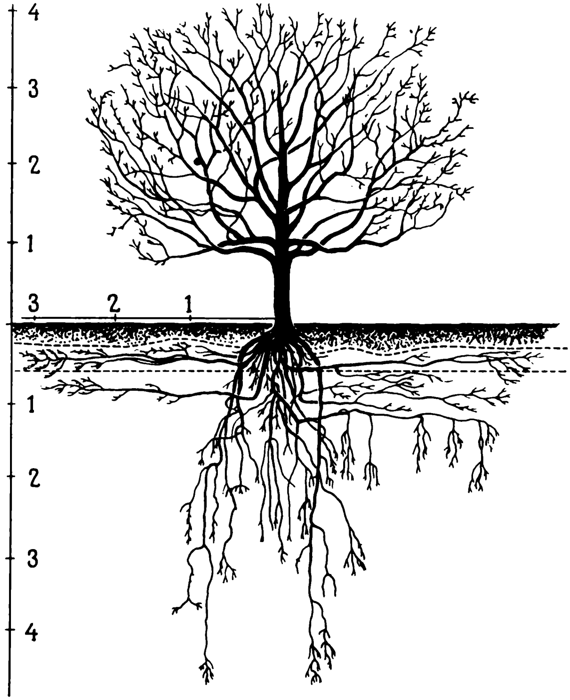


Fig. 38. Vertical section of 20-year-old Antonovka Obyknovennaya apple tree in Lenin State Farm, the Moscow Region, 1954. The rootstock is *M. sylvestris*; roots penetrated down to 4.5 m

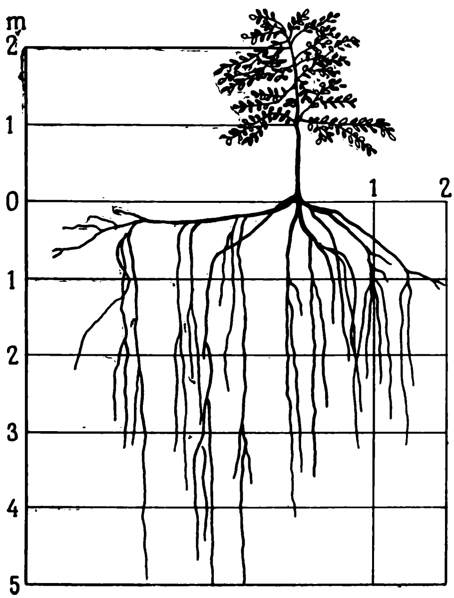


Fig. 39. Eight-year-old Vladimirskaya sour cherry on Mahaleb cherry, in Krasnodar Territory. Roots penetrated down to 5 m; soil is 3rd terrace of deep chernozem

distributed in the top 1 m on Chinese apple rootstock, 1.3 m on Doucin III, 2 m on *M. sylvestris* and Anis seedling, and 2.5 m on Antonovka seedling.

On different soils in Moldavia the roots of apple, plum, apricot and quince extend to 2 m depth and those of pear to 2.5 m.

In Uzbekistan, the roots of Rosmarine blanche apple on Siberian apple descend 6.2 m deep and Arabian Baba apple only 1.5 m, while the roots of pears on vigorous rootstock penetrate to 3.6 m depth and on quince to 1.6 m. In the Crimea, the roots of apple on Paradise apple and pear on quince extend to a depth of 4 and 5.5 m.

In Hungary, 30-year-old apricot trees on wild apricots whose main mass of roots was in the top 60 cm had part of the roots extending to 2.3 m depth; when grafted on plum the respective figures were 60 cm and 1.8 m (I. Tamaczi, 1958). The roots of a 24-year-old walnut-tree penetrated 2.2 m deep, while their bulk (60.2%) was distributed in the top 40-60 cm (P. Maliga and I. Tamaczi, 1957).

The total number and length of descending roots may be very considerable. For instance, excavations at the Chkalov state farm in the Crimea showed that the total length of all tree scaffold and fibrous roots of 45-year-old Sary Sinap apple equalled 2.7 km, of which the vertical roots accounted for 1.6 km and the horizontal roots for 1.1 km; 36 per cent of their total number (30-40 per cent in Kazakhstan) was within tree spread and the remaining 64 per cent outside it, while in Georgia the respective figures were 38.9 and 61.1 (Fig. 40). Such a tree in the Crimea yielded from 0.5 to 1 ton of fruit annually.

In the same orchard but on a site with a high water table the excavations of Reinette de Champagne apple trees, 25-year-old, revealed a root depth of only 1.3 m and a total root length of 523.6 m, the vertical roots accounting for only 77 m and the horizontal ones for 456.6 m, of which 216.6 m were within the tree spread and 240 m outside it (Fig. 41). The percentage of descending roots for a total of seven excavated trees varied from 13.6 to 64.7, while the percentages for length were from 11.2 to 58.12. This seemed to depend on a variety of factors, but particularly on the soil factor and the position of the water table. Thus, excavations of Reinette de Champagne and Candille Sinap apple trees revealed an almost complete absence of sinker roots

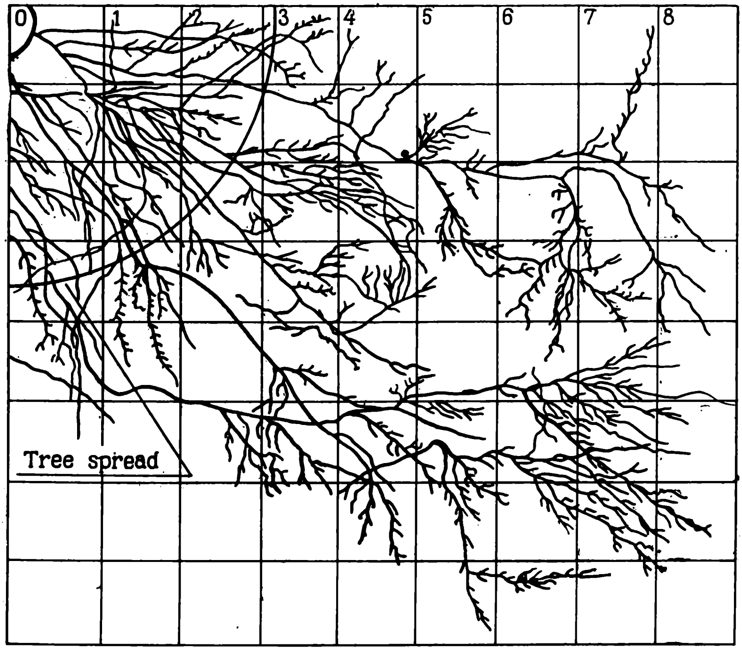


Fig. 40. 45-year-old Sary Sinap apple on *M. sylvestris* in the Crimea. Tree spread is 3-5 m and root spread is 11 m. Tree care within tree spread will be of little use

wherever there was a high water table or very heavy soil or hard rock, all limiting root depth.

The root systems of sour cherries in the Moscow Region, produced from stem cuttings are usually inferior, compared to grafted trees, in scaffold root development though they are superior in root net development. The roots of own-rooted plums in Moldavia have been found to be shallower than in grafted plums.

The root systems of soft fruits are very ramified, rather small and relatively shallow. The bulk of their roots is distributed in the top 30 cm while a number of sinker roots may penetrate to a depth of 50-60 cm in the strawberries and 1 m and even more in the other species. For certain peculiarities of the root and aerial parts of the strawberry and the raspberry see Fig. 42 and Figs. 43 and 44 respectively.

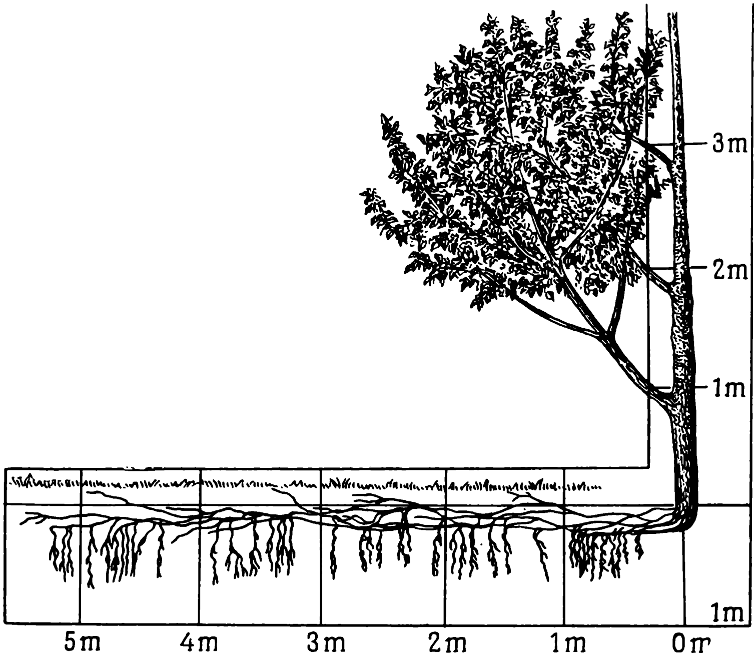


Fig. 41. 25-year-old Reinette de Champagne tree on *M. sylvestris*, the Crimea. Soil conditions are poor due to high water table (up to 1 m); root system is distributed in the top 75 cm; tree is weak and crops poorly

Under favourable conditions root penetration in fruit trees is fairly rapid. Thus, the roots of fruit trees on vigorous rootstocks penetrated at the age of 4-12 years 3-5.5 m and even 9.5 m deep under favourable conditions (in the Kuban area), while the roots of trees, even 30 years old, penetrated only 1-1.5 m deep under bad conditions (in the Crimea). The roots of dwarfing rootstocks—Paradise apple and quince—may also descend 4-5.6 m deep.

Investigations in the Crimea (Simferopol district) showed that 35-year-old Sary Sinap apple trees yielded up to 300 kg of fruits per tree with a root depth of 4.6 m, while trees of the same variety and age yielded only 100 kg of fruits, having a root depth of 1.5 m, which was mostly due to a high water table.

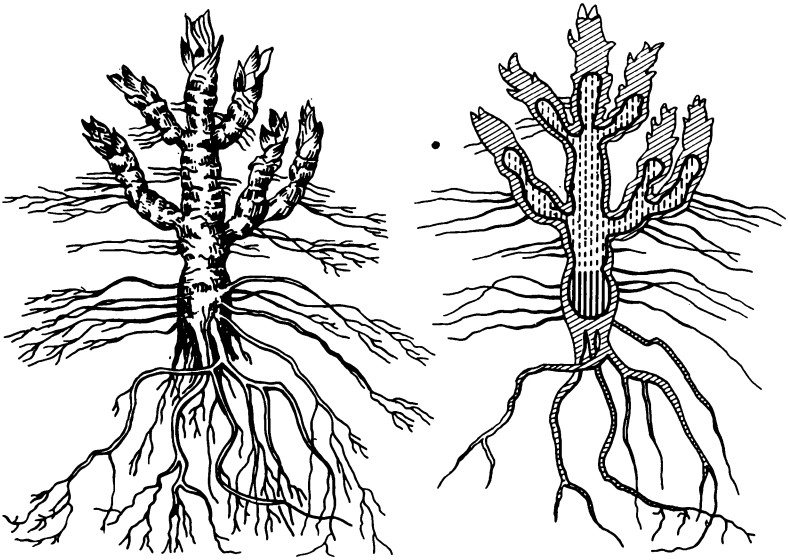


Fig. 42. Four-year-old strawberry plant, general view (*left*) and longitudinal section (*right*)

In the author's studies in the Moscow Region which included complete excavations of 22 apple trees, from 6 to 22 years old, over a period of 10 years (1953-1963) the roots reached 3.5 m in diameter at the age of 7 years, 5 m at the age of 14 years and 8-9 m at the age of 20-22 years. Consequently, at the age of 7 years the space free of roots with rows spaced at 8 m was 4.5 m; at 14 years, 3 m, and at 20-22 years there was no free space left, with roots overlapping by an average length of 0.5 m (Fig. 45). However, even at the age of 20-22 years there is a free space of 1-3 metres between the crowns of trees of different apple varieties growing in neighbouring rows.

It has been established that a year-old seedling apple in the Moscow Region may develop a main root 60 and more cm long in one summer while horizontal root growth averages 23 cm at the age of 7, 15 cm at 14 years and only 8 cm at 20 years. It should be remembered that the older the apple tree the considerably more growing axial roots in its root system.

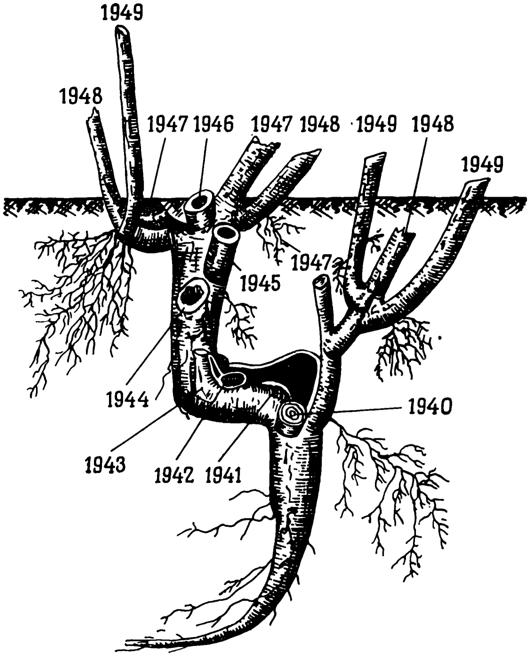


Fig. 43. Raspberry stock showing new cane growths at the base of two-year-old canes (after Z. A. Gerasimova)

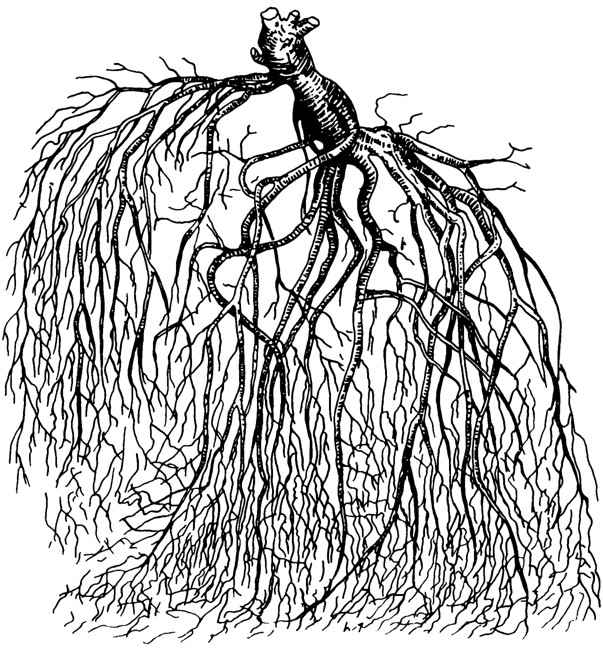


Fig. 44. Root system of black raspberry (after Gruzdev and others)

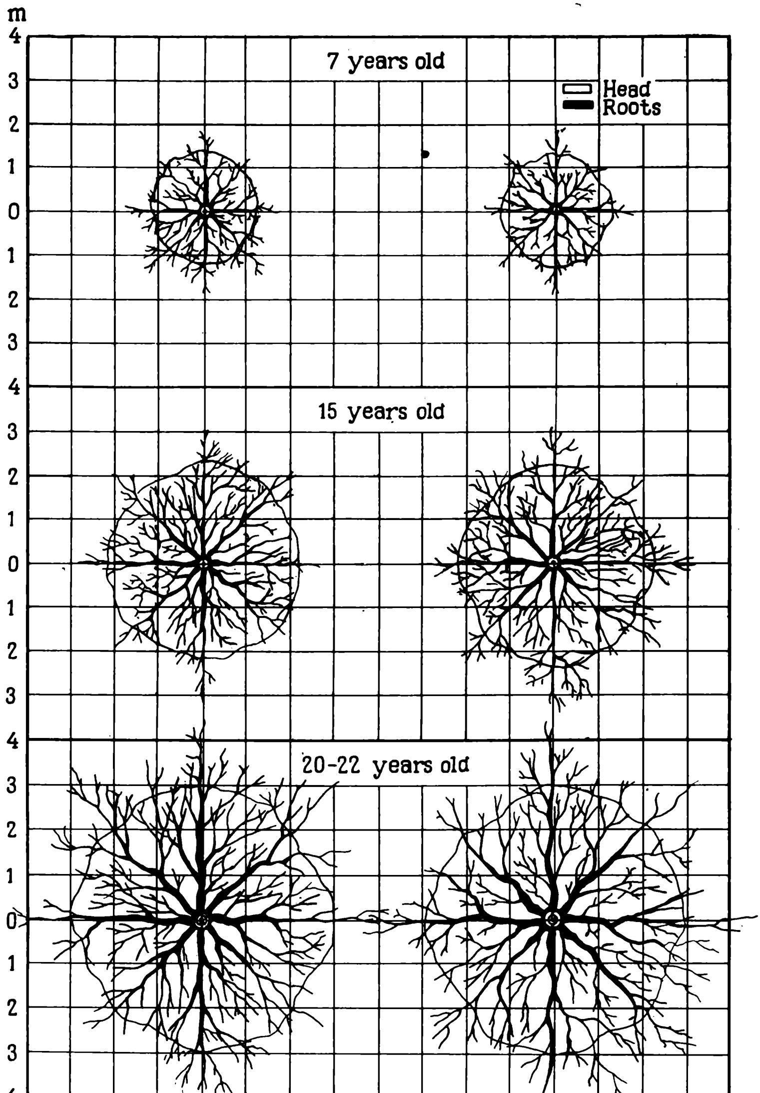


Fig. 45. Relation of tree to root spread in different age periods in Antonovka Obyknovennaya on seedling Anis Sery

Usually when not checked by unfavourable climatic or soil factors, the main mass of both horizontal and vertical roots tends to sink deeper into the soil with age. This is influenced, however, by the individual characters of rootstocks, the root systems of Chinese apple and Doucin III being shallower than those of *M. sylvestris* and of Anis and Antonovka Obyknovennaya seedlings, which speaks in favour of the latter three.

As a rule, the more to the south tree and soft fruits are grown the deeper their roots extend. However, root distribution may be very shallow even in the south. This is usually the case wherever there is a high water table, gravel layers or cemented formations, particularly in the alluvial soils of the southern zone of the U.S.S.R.

An ideal fruit tree root system should be evenly distributed in a wide and deep sphere, rather than be one-sided or uneven, so that it can rely for its nutrition on a very extensive volume of soil. In addition, such a fruit tree is mostly drought- and frost-resistant.

As shown by Soviet and foreign fruit growers, fruit trees with a powerfully developed root system have a better appearance and greater longevity. Such trees are hardy and bear high and regular crops. That is why it is so important to stimulate by appropriate cultural practices deep root penetration. When determining depth of ploughing and fertilizing the grower should actually measure root depth in his orchard.

All this makes it imperative for the fruit grower to know all about the soil and the root size and depth in the orchard he manages before he can choose the cultural system that will benefit him most.

There are easy and reliable methods of determining root depths. College students study these methods during their orchard practice.

Aerial Portion

Development of plant from seed. P. G. Schitt (1940, 1952, 1958) considers that tree and soft fruits reveal a great deal of similarity in their individual development which simultaneously reflects ageing and rejuvenation processes. The difference is only quantitative, e.g., in the speed of ontogeny in different plants and in the rate and character of

phenologic phases. Raspberry canes, as an example, do not live long: they grow in the first year and bear fruit and die off in the second. The plant is restored by new canes which arise from reserve buds on roots and on canes.

The branches of black and red currants are longer-lived—6 to 10 or more years. However, extension growth only goes on for 2 to 3 years—particularly the first year, after which terminal rosettes with fruit buds appear for two or more years; in subsequent years the tips of branches gradually die away while the shrub persists due to the appearance of new shoots from the base of scaffold branches.

A somewhat slower rate of development is characteristic of the stone fruits (cherry, plum, peach and apricot) and a still slower one of the pome fruits (apple and pear). Out of the tree fruits the closest to the soft fruits are the shrub-like sour cherry and plum distinguished by a shorter ontogeny and an ability for sucker formation which at the same time is an indication of increased ageing.

The difference between the stone and pome fruits lies in that due to early maturity of the former (in favourable conditions) they are able, unlike apples and pears, to produce two series of shoots in one growing season, i.e., to achieve extension growth 2-3 times in case of sour cherry and plum and even 3 times in case of peach and apricot.

The size of a plant increases at first through the growth of the first stem, or leader, and then through the annual, often very numerous, growths or shoots. A characteristic feature of shoots is a great difference between them in the way their buds start into activity. This varies with the individual characters of the species and varieties involved as well as with the environmental conditions.

Characteristic peculiarities of buds. It is as important to know the statics of buds, i.e., their form, structure, etc., as it is to know their dynamics—their behaviour, their role in the building of the habitus of tree and soft fruits. P. G. Schitt established certain principles of bud behaviour common to all tree forms, including tree and soft fruits. This knowledge is of prime theoretical and practical importance.

Activation of buds, i.e., their ability to become completely or partly active at the time of new extension growth in the spring. For instance the stone fruits possess a high activation of buds, for almost all buds on a shoot become

active, while the pome fruits are less active as a considerable part of their axillary buds may remain dormant.

Early maturity of buds, i.e., their ability not only to develop on a young shoot but also to grow into a summer shoot during the same summer. This ability is manifested in the buds of sour cherry, sometimes sweet cherry and plum, as well as apricot, almond and peach. This quality is particularly well-pronounced in these fruits in good, long summers. "The early maturity of buds is one of the visual and objective indications of the speed of the ontogenic development of plants of different species" (P. G. Schitt, 1952).

Late maturity of buds, i.e., their ability to produce only a year-old shoot in one growing season and transform into a branch during the next year, which means that they have a two-year cycle of development. This quality is characteristic of most apple and pear varieties.

Heteronomy of buds on the same shoot is common in buds of tree and soft fruits, both in hybrid seedlings and in the fruit-bearing stage.

Shoot-producing ability, i.e., an ability of plants to induce buds to develop shoots of the growing type; when this ability is not well-pronounced very shortened shoots of the fruiting type are produced in the form of rosettes with a few leaves.

Shoot-reproductive ability, i.e., an ability of fruit plants to develop shoots on mostly denuded scaffold branches and limbs of a later growth period. This is due to the fact that the dormant, or reserve buds are able, under certain conditions, to become active and produce shoots. The shoot-reproductive ability and the longevity of buds are of prime importance for the work of fruit growers in pruning and rejuvenation.

P. G. Schitt also established the characters of storiness and morphological parallelism in tree and soft fruits.

Storiness is an ability of plants to produce longer growths on a limited part of a branch and weaker growths, usually of the fruiting type, or none at all on the rest of the branch. This storiness in the distribution of shoots along the scaffold branches in tree- and even shrub-heads is accounted for by the discrepancy between excessive new bud formation, particularly during the early growth periods, and the slowed up intake of nutrients by plants during these periods.

Tiers appearing on the central leader are more pronounced than those on the scaffold branches of the first to third orders. Consequently tiers arise in the earlier stages of a tree's ontogenic development (during its first three growth periods) or, in other words, when it is young, gradually disappearing from base to tip on the central leader as well as on the main scaffold branches of the higher orders. These branches, of fourth, fifth and higher orders, either develop fruiting wood or are of the fruiting type themselves.

The character of storiness (number and size of branches, distance between tiers, etc.) depends on specific and varietal peculiarities, age of tree, natural conditions and management. Storiness, though to a lesser degree, is also evident in soft fruits—currants and gooseberry.

In any new growth of a shoot of any species advantage is on the side of the terminal bud as compared with all the others located on the lower part of the shoot. N. A. Maximov considers that due to enzymal activity in the tips of shoots the nonactive compounds of protoauxin flowing downwards from the leaves are transformed into auxin. When its concentration is low it stimulates the growth of lateral buds as it moves down until its concentration becomes high and it starts to inhibit their growth. After the tip of a shoot is cut the amount of auxin drops, which stimulates the activation of the lateral buds on the shortened shoot.

There has been an accumulation of new data on the substances regulating flowering and new growth which suggests that not only auxin is responsible for growth but also gibberellin, kinin and certain inhibitors (A. C. Leopold, 1962).

The strongest lateral shoots are the highest on last year's wood; the lower they are, the weaker, depending on variety; the lowest buds stay dormant, due to which certain varieties have too much bare wood and require special pruning as a remedy.

This regularity in the distribution of the strongest lateral branches and shoots in the upper part of the heads of fruit trees is a result of their century-long development—their phylogeny—in forest communities. Despite the spaced distribution of fruit trees in orchards they have retained this quality inherited from centuries of cramped growing. The fruit grower should bear this in mind when determining

the distance in rows and between rows when planting, pruning and shaping his trees.

Of great importance is also the close and regular dependence between the number of order of branches and their biologic qualities (Ye. I. Guseva, 1951):

(a) longevity and growth vigour of branches decreases from the lower to the higher orders;

(b) leaf density—number of leaves to length of shoot ratio—increases from the lower to the higher orders while the size of leaves and the length of internodes decreases;

(c) the higher the order of branches the greater the number of fruit buds and effective flowers on them compared to dormant and wood buds.

Morphological parallelism consists in the relative similarity of growth and development of tiers on fruit tree limbs of the same order and growth period as well as in the relative similarity of the growth, development and distribution of growth and fruiting formations within tiers. This phenomenon is a result of the entire history of the habit development of arborescent species and of certain inherited peculiarities of their growth and development due to which branches of the same age and vigour similarly positioned in the head have buds in the same developmental stage.

The phenomenon of morphological parallelism, or relative similarity in growth and development, is clearly evident in both one-year-old seedlings and mature tree and soft fruits. Parallelism can be seen, for instance, in the growth and development of the main limbs which being in relatively similar conditions are relatively similarly developed—in length, girth, growth vigour, order of branching and number of buds.

Cyclic renewal (self-thinning) of branches (after P. G. Schitt). Fruit trees, whether they start from seed or from graft, develop at first the stem and then, in subsequent years, the main limbs of different orders. It is a well established fact in the practice of fruit growing that the first crops on young trees are usually formed well within the head, e.g., in apple on the short twigs on the scaffold axis of the first order, while vigorous shoot growth predominates on the outer boundary of the head. After a few years these fruiting shoots, spurs, etc., begin to form fruit buds and the tree enters the fruit-bearing stage. These shoots are shorter-lived than the scaffold branches of the same age

and order. Thus starts the process of the dying off of shoots, or the gradual denudation of scaffold branches from base to periphery, on all perennial fruit-bearing trees.

The process of the dying off, or denudation, of shoots is based on the inherited characteristics of the species and variety growing in the given environmental conditions and also depends on the age of the tree. Thus, for instance, the average life expectancy of a shoot of apple, pear, sweet cherry and certain varieties of tree-like sour cherry is 8 to 12 years, while for apricot, peach, plum and shrub-like sour cherry it is 5 to 4 or even 2 years. In other words, the dying off of shoots, or denudation of trees in most apple and pear varieties proceeds much slower than in apricot and plum. Given similar environmental conditions this leads to a considerably greater denudation of the scaffold branches in the stone fruits than in the pomes. Consequently, the periphery of the head, or the leaf-growing zone is smaller in the stone fruits compared to the pome fruits.

The same process of the receding of shoots from centre towards periphery occurs in the soft fruits but in smaller scope and shorter sequence.

The longevity of branches is greatly influenced by the environmental conditions, especially lighting, temperature, and air humidity. Thus trees favourably situated from the point of view of air and light are distinguished by bigger heads, greater leaf surface throughout the head as well as by a slowed dying off and better restoration of branches of different orders than their sister trees placed in less favourable conditions in the same orchard.

The phenomena of storiness, morphological parallelism, dying off and renewal of branches in the head of fruit trees should all be taken account of when shaping plants in the nursery, and pruning, rejuvenating and regrafting trees in the commercial orchard.

Formation of branches. Fruits and most of the leaves are borne on fruiting and growth shoots, that is why it is important to know how they are formed. Growth and fruiting formations in their entire range appear on strawberry in the course of one year; on raspberry, in two years; on gooseberry and currants, in three to four years; on sour cherry and apple, in five to ten or more years.

The pome fruits form wood buds in the axils of leaves on current year's growth. The next year the ones placed

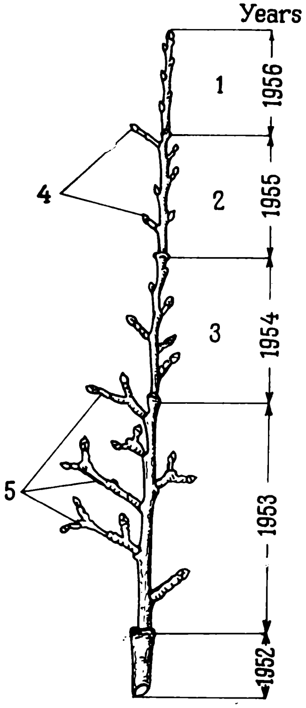


Fig. 46. Fruiting apple branch, arrows showing age divisions:

1—yearling wood; *2*—two-year-old wood; *3*—three-year-old wood; *4*—fruit spurs with fruit buds; *5*—fruit spurs that have borne fruit and produced fruit buds again

higher develop into shoots while others turn into fruit buds. On the third year the fruit buds produce fruit and one or two short growths, thus developing into a spur (Fig. 46).

Producing one or two short growths every year a spur branches and gradually develops into a spur system which may be three to 15 or more years old. Often maiden laterals of certain apple varieties form lateral or terminal fruit buds during the first year, so that a spur arises in the second year, but sometimes a fruit bud may be formed on a former maiden lateral in its third to fifth year.

Growth and cropping vigour of apples depends on the correlation between the different types of growth and fruiting branches, viz., vegetative shoots, spurs and mixed laterals. Poor growth and development are accompanied by abundant spur-system formation, and vice versa, for vigorous growth leads to the formation of many young spurs. By cultural practices, notably pruning and feeding, growth

may be accelerated or slowed down to produce more current year's wood and fruiting shoots of the productive type, thus regulating growth and cropping vigour in fruit trees.

Extension growth of fruiting shoots stops much earlier than that of vegetative shoots; in case of spurs and particularly older spur-systems it lasts for 10-20 days; dards and brindills grow a bit longer, while the tips of scaffold branches grow much longer—two to three months. Extension growth may be very small, notably in older spur-systems; in unfavourable conditions it may be down to several or even one or two millimetres. With annual growth of that order spur-systems and even individual spurs seldom blossom and set no fruit even when they do.

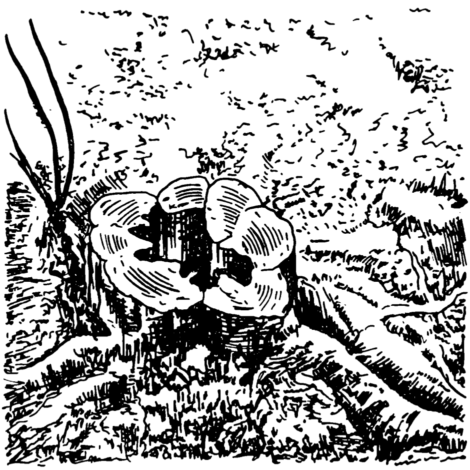
Correlation and Localization

Correlation is the relationship between the structure and functions of parts of a plant organism which is a result of the adaptation of the organism to the conditions in which it grows. Plants usually reveal correlation of two types—biomorphological and correlation of growth (D. N. Beketovsky, 1959). In the first case some characteristic features, as, e.g., shape or colouring, repeatedly occur in different organs of one and the same plant. Thus the Sary Sinap and Candille Sinap apples are distinguished by their pyramidal heads and also by the elongated shape of their leaves, fruit and seed. It is well known that the leaves, shell of nut and skin of seed of the hazelnut (*Corylus avellana* var. *purpurea*) are all coloured dark-red. Similarly the Niedzwetzky apple has reddish leaves, petals, stamens, fruit and seed.

Correlation of growth has been a known fact for a long time, notably in the case of a vigorous root system going hand in hand with a vigorous top system and vice versa. There is also a correlative connection between parts of the head and parts of the root system on the same side of a tree in that each scaffold root has a corresponding scaffold branch. This was pointed out by P. G. Schitt who considered that as a fruit tree grows older it may even split in several parts (Fig. 47) each served by its counterpart in the root system.

And this is also evidence of another correlative connection in plant organisms—that of localization. Labelled

1



2

Fig. 47. Dismemberment of trunk in fruit plants:

1—old pear tree (after P. G. Schitt in Uman); *2*—old apple tree (after Z. A. Metlitsky in Moscow)

phosphorus introduced into certain roots of a 25-year-old apple tree mainly concentrated on the corresponding side of the trunk, markedly decreasing in amount from periphery to centre. When introduced by foliar spray labelled phosphorus became incorporated into nucleoproteids whose activity was higher in the treated leaves than in the untreated ones of the same branch. Correlation between individual parts of the root and shoot systems has been established for seedling apple trees (T. P. Yevdokimova, 1955). It was also studied by N. D. Spivakovsky (1958), G. Spinks and S. Barber (1948) in Canada on conifer seedlings. It must be said that no definite correlation has been established for budded or grafted trees (Y. A. Belavin, 1956). This may be due to grafted organisms being unable to establish the same anatomic fusion of tissues as in the case of seedling plants.

During the first half of summer when an apple tree is in active growth labelled phosphorus taken up from fertilizers concentrates in terminal growths and in young leaves. In the autumn labelled phosphorus concentrates in the lower branches and older leaves. There is direct ratio between the amounts of phosphorus in branches and in the leaves on them (Y. Z. Zelenskaya, 1957).

The markedly bigger phosphorus intake by apple trees in the spring compared to the autumn shows that the aerial portion of trees is in greater need of phosphorus in spring than in autumn. The root system, however, requires phosphorus in the autumn, too, which is confirmed by a greater phosphorus intake by the roots in the autumn. The speed of labelled phosphorus translocation is fairly high in the first hours after fertilization and in spring it may reach over 30-35 cm per hour, being considerably lower in autumn. It has been found, however, that the movement of nutrients, particularly phosphorus, from branch to branch takes place only when the concentration of such substances is much higher in some branches than in the others (V. A. Kolesnikov and I. Palkevi, 1963).

The greatest amounts of labelled phosphorus were contained in seeds, with bearing spurs and their leaves coming next, and the lowest in unproductive spurs and their leaves and in the flesh of fruit. Great amounts of labelled phosphorus were also found in young shoots arising from dormant buds on the older parts of branches (N. D. Spivakovsky, 1957).

It has been found by the author (1957) that (1) markedly more labelled phosphorus is taken up by flowers, and later by ovules and fruits, particularly following seed formation, than by the leaves of the same spurs, and (2) labelled phosphorus intake by younger spur systems is greater than by older ones even if the difference is only one year.

The growing parts of a plant are supplied by nutrients mostly from the nearest leaves along the branch. This may explain the localization of such processes as photoperiodism and leaf shedding occurring in certain environmental conditions (V. O. Kazaryan and N. V. Balgazyan, 1955).

However, this is just one aspect of plant biology. For plants always reveal physiological predominance of some parts of organs over others. This is first of all evident in the priority transport of nutrients to such parts of organs. For instance, in the later half of summer stored nutrients do not move from one lateral into another; they can be said to be autonomous and independent one from another. The picture is quite different in the case of branches with fruit when localization is blocked and they heavily draw on the nutrients in the neighbouring branches without fruits.

Consequently fruit and, perhaps seed, of apples and presumably of other species possess a much greater ability of attracting organic substances than the vegetative parts, e.g., leaves of the same plant. Plant organs are physiologically interdependent to a highly varying degree (I. I. Tumanov and E. Z. Gareyev, 1951).

According to U.S. research (W. H. Chandler, 1957), one or more first-order branches of alternate bearing trees may have their own alternate bearing habits and bear fruit in the "off" years, when all the other branches do not. This phenomenon has also been established for plums, such as Sakharnaya, which tend to have an alternate bearing habit. Individual spurs have been observed to bear fruit in the "off" years due to localization.

Localization as well as the domination of certain plant organs over others are plant characteristics of interest to fruit science and practice alike, notably in such cultural practices as pruning, pinching, crop control, root care, etc.

Regeneration of Fruit Plants

Regeneration is the process by which a plant organism regains its normal form altered by the loss of, or damage to, a part. This includes restoration of whole plants from their part. Regeneration is observed in natural conditions, due to damage by frost, pests and diseases, and may also be induced by cultural practices when propagating by cuttings, grafting or budding, when pruning or rejuvenating, when cutting roots in propagation work, transplanting and ploughing.

The author's long-standing studies in the southern fruit-growing zone (the Crimea and Kuban area) showed that it is inadvisable to cut apple roots exceeding 8-10 mm in diameter because in conditions of irregular soil moisture such roots heal poorly and produce few or no lateral roots (Fig. 48).

Apple roots not thicker than 12-15 mm heal successfully when cut in ploughing (the Ukraine). A dense net of rootlets is formed at the place of wound in 45-60 days. Ploughing should be done in the spring or in autumn. Roots cut in these periods produce good growth (D. O. Gorbatyuk, 1953). Growth of damaged roots proceeds better on irrigated, fertile or fertilized soil than on poor, nonirrigated soil. Disregard of this leads to poor growth and reduced cropping.

Any wound caused during a cultural practice or by adverse conditions may interfere with some vital process in the plant organism. Thus a heavy pruning of roots or branches may hamper the normal correlative relations between them, e.g., the metabolism between the aerial portion and the root system, and lead to reduced cropping and shorter life, apart from expense involved in healing.

After a wound has been inflicted two processes occur: (1) healing, e.g., in pest, disease and frost damage resulting in fissures or other surface damage, in cutting branches to the base, etc.; and (2) regeneration of damaged parts during and after the healing of the wound when clipping roots, shoots or branches or in rejuvenation work.

In the first case the injured surface cells darken and die off while underneath them the undamaged, live cells become suberized on the outside and produce a layer of corky cells sealing the wound. At the same time or a little

Fig. 48. Apple roots damaged by cultivating tools (note absence of new root growth on thick roots as distinct from thin ones)

earlier there is usually a considerable development of new tissue in the wounded region. This tissue known as callus, is formed of soft parenchymatous tissue, mostly of cambium, as a result of meristematic activity. Its characteristic feature is growth of the corresponding cells towards the wound. Callus may also differentiate into new lateral meristems, cambium and phellogen, continuous with the original ones. These new meristems proceed to form vascular tissue and bark at the same place and of the same kind as the adjacent uninjured meristems (V. F. Razdorsky, 1955). In such cases not only is the wound covered, but it is rendered completely unnoticeable.

The healing of wounds is greatly assisted by the so-called wound hormones which are chemical substances produced from the contents of the injured cells. The irritation these substances cause acts not in the wounded layer itself but immediately below it and brings about a profound change in the vital processes of the cells, increasing the energy of respiration, improving metabolism between cells, etc.

Another case of natural healing of wounds is gum formation on stone fruits. Gums which are derivatives of carbohydrates protect by their viscous mass the adjacent uninjured cells.

The processes of regeneration are influenced by a number of conditions, both internal and external. For instance, of great importance not only in wound healing but also in the regeneration of a complete plant from a root or stem cutting, is the age of a plant as a whole as well as the parts to be regenerated. As a rule regeneration proceeds quicker in younger plants. Pome fruits usually heal their wounds better than stone fruits; so does Pippin Shafranny compared to Antonovka Obyknovennaya apple.

It is a general rule that a tree in good growth and care can rely on an adequate supply of nutrients in the wounded regions which accelerates healing processes.

The fruit grower should assist the course of the natural processes of wound healing by such methods as making clean pruning cuts, paring the wound to a smooth surface in breakage, sealing wounds with wax and in general by good tree care.

CHAPTER FIVE

•

PERIODICITY OF GROWTH AND DEVELOPMENT OF FRUIT PLANTS OVER THE YEARLY CYCLE

Root System

Dynamics of root growth. As far back as 1852 A. A. Bobrinsky was the first to observe that the roots of arborescent plants have two periods of growth in one growing season. He held that while plants grow only during the most favourable part of the year their roots continue growing during the winter, when the plants rest.

Several workers observed from three to six flushes of root growth in one growing season in apricots, apples, peaches and certain other fruit trees.

The analysis of a large body of data on root growth dynamics of the principal tree and soft fruits collected by the author over a period of 25 years in the Crimea and Moscow Region showed that, depending on the internal and external factors, plants have from one to several flushes of root growth in one growing season. It was also established that these flushes of growth vary according to the depth of distributions, as was found in 1939 in the Crimea on apple roots at the depths of 0-35, 35-55 and 55-75 cm. The absorbing roots, for instance, mainly grew in the spring in the top 35 cm, due to better heating, moisture level and aeration of the soil, while in the summer, due to draught, deeper lying roots exhibited more vigorous growth.

Apple trees in ten-year-old orchards show an inverse relation between their root and top growth, which apparently helps the trees to make a better use of the nutrient substances and energy required for their growth and metabolic activity. The winter period of rest may be conventionally accepted only for the above-ground systems of plants while their root systems exhibit vigorous activity (S. A. Samtsevich, 1951).

There is a vigorous root growth in the spring, which slows down after the reserves of nutrient substances, have

been depleted, while the products of photosynthesis are used for the speediest growth of shoots and the cambium (W. H. Chandler, 1957).

In winters with a heavy snowfall apple root growth in the Moscow Region continued up to January, until the air temperature around roots dropped down to +2-0°C. In warm winters in the south the roots of tree and soft fruits, e.g., apples and currants in the Crimea and apricots in Armenia, grew throughout the year.

In Daghestan apricot root growth goes uninterruptedly throughout the year, but irrigation and fertilization should be carried out during the minimum root growth phases so as to ensure the optimum conditions required by apricot trees during the maximum root growth phases which fall on early summer and autumn (D. I. Vinograd, 1939).

To sum up, the root systems of tree and soft fruits have no organic period of rest though, on account of adverse conditions, they are very often in a state of forced rest.

The author's studies over the last 12 years in the Moscow Region showed that under the optimum conditions of the moisture regime which obtained in 1953 due to irrigation and excessive rainfall apple roots grew relatively evenly throughout the year, the active roots constituting from 48 to 70 per cent of the total root length. With no irrigation and average rainfall, root growth occurred in flushes.

Root growth is longer and more even in non- or poorly-productive years before bearing, or with excessive shoot growth after the start of bearing, and in all trees which get sufficient and timely fertilization, irrigation and mulching.

By parallel observation of active root growth in two adjacent apple trees under the same management in the Crimea the author found that the tree with a big crop showed no active root growth throughout the three summer months while the other tree, with no crop at all, was inactive only for less than one month. In this case it may be assumed that the carbohydrates synthesized by the tree with a big crop were used exclusively for fruit formation thus retarding active root growth.

The root systems of apple trees are able at any period of reduced growth to go over to intensive growth if provided with optimum moisture and nutrition.

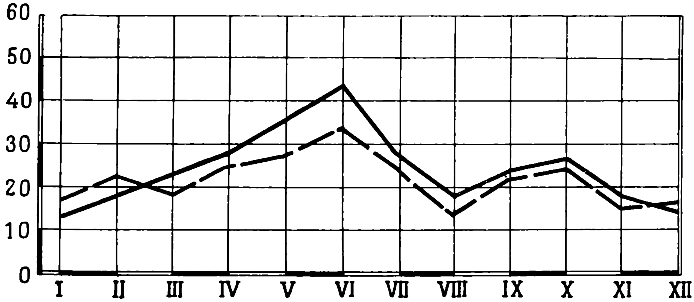


Fig.49. Dynamics of apple root growth (continuous line stands for black fallow and broken line for grass culture; after Kacharava in Georgia)

In the spring, vigorous leaf growth often preceeds root growth but under certain conditions the reverse is also possible. Depending on the moisture content of the soil active root growth at greater depths or at the surface may begin prior to top growth but its vigorous growth, i.e., its first peak, coincides with the appearance of a considerable leaf surface.

The problem in the author's opinion is not whether the roots or tho leaves are the first to start vegetation but how to induce the mass of active roots to develop timely, i.e., by the time the leaves appear.

As established by many Soviet and foreign investigators the root systems of tree and soft fruits usually have two periods, or waves of increased growth—in the spring (May-June and part of July) and the autumn (September-October), and two periods of reduced growth or no growth at all—in the summer and winter. Consequently roots grow for 4 to 5 months in a year.

Extensive investigations conducted over many years by the Department of Pomology of the Timiryazev Agricultural Academy in Moscow including various fruit-growing zones of the U.S.S.R. showed that root growth is universal in spring and may not occur in other seasons on account of certain conditions. Under conditions of sufficient watering (75-85 per cent of total water-retention capacity) or above-average rainfalls, moderate cropping and good cultural practices root growth is relatively even from spiing to winter and, in warm winters in the south, throughout the year (Fig. 49).

The author's studies in the Moscow Region showed that the roots of bearing apple trees (Antonovka Obyknovennaya on Anis seedling) grew 6 to 7 months every year and 9 months in one year when snow fell on still unfrozen earth. Studies on root growth over a period of 10 years showed that for four years root growth took place in 2 flushes, four years at the rate of 3 flushes, one year only one flush and one year four flushes. Maximum active root growth was 30 to 90 per cent of the total root length under irrigation and 18 to 70 per cent without irrigation. Active root growth was more vigorous in the spring during five years and in the autumn also during five years. It was found that there may be no root growth in a droughty autumn without irrigation, while in the same period but with above-average rainfalls or irrigation root growth may be more vigorous than in the spring.

It can be seen that the root systems of tree and soft fruits, instead of having two big and two small growth periods, grow over the year in flushes (or waves), from one to three or more, less often from one to two and still less often evenly throughout the year. Root growth at different depths varies in vigour and season depending on the external factors (V. A. Kolesnikov, 1959, 1963).

Periodic changes in the functions of the root during its development. The root system of tree and soft fruits consists of roots that belong to four different types: axial, absorbing, intermediate and conductive. The periods of vigorous vital activity in plants, such as shoot and root growth, flowering and fruit formation, are principally provided for by the numerous absorbing, or active, roots covered by primary cork and root hairs which supply the plant with water and mineral substances. In the course of summer absorbing roots change anatomically under the influence of various factors and become intermediate roots. They lose their root hairs and decrease in number while in the course of winter they undergo further anatomical changes, turning dark though still retaining their primary structure. At the same time many absorbing roots turn into conductive roots. There are certain periods in the life of a plant in the course of its growing season as well as during the winter when only intermediate and conductive roots are present and yet the plant appears to live normally, at any rate its water intake goes on uninterrupted.

It is obvious from this that the knowledge of the relationship between the anatomy and the functions of the various types and parts of roots has a great practical as well as theoretical significance, for it is essential to assess the behaviour of both individual roots and whole root systems. One of the most important indications which characterize the physiological condition of a root is its degree of *suberization*. The degree of suberization varies greatly with the period of vegetation and the external factors. Suberization may affect up to 100 per cent of the length of all the absorbing roots (I. A. Muromtsev, 1963).

The absorbing roots of primary structure may be more or less yellow or even dark and still be alive. L. A. Ivanov (1916) observed in one of his early works that even completely dark absorbing roots of a pine are little suberized and remain alive, retaining their capacity for water intake. Darkening of colour may be caused by adverse conditions. In winter months only surface cells at growing points are heavily suberized.

In the state of growth the protoplasm evenly fills the meristematic cells, whilst in the state of rest it shrinks away from the cell walls to form globular yellow corpuscles. When rootlets are at rest the vessels in them are often formed directly in the meristematic region for there is no cell elongation region at that time. In growing rootlets vessels are formed at a long distance from the tip. At rest the entire surface of absorbing and axial (growth) roots down to the meristem is covered by epiblema, which is almost never suberized; under it lies the exodermis which is suberized, the degree and nature of suberization varying according to species. The arborescent plants under study were characterized by complete suberization of the exodermis cells, with numerous permeable unsuberized cells that are sometimes equipped with special apparatus for water intake (L. N. Zgurovskaya and Yu. D. Tselniker, 1955).

According to L. N. Zgurovskaya and Yu. D. Tselniker, the primary bark does not die off. The darkened roots are impregnated with a substance similar to vagin but not with cutin or suberin, and therefore they are capable of letting water in. On the example of the roots of oak, ash and maple these two workers confirmed and enlarged data on the darkened absorbing roots of arborescent species

being capable of water intake through the permeable cells. They do not think that the impregnating substance is suberin while W. S. Rogers (1939) and I. A. Muromtsev (1959) believe it is.

An anatomical analysis of lemon seedling roots carried out by Ye. V. Noskova (1956) led to the discovery of permeable cells in the epiblema and, under it, of special groups of permeable cells among the cells of primary and even secondary origin. Through these cells nutrient solutions are taken in and the mycelium of the endotrophic mycorrhyza penetrates and activates the process of suberization.

K. P. Cossman (1940) who studied soil moisture observed root hairs on the roots of citrus trees and confirmed the presence of permeable cells which obviate the passage of nutrient substances and mycorrhyza mycelia.

I. A. Muromtsev (1963) found that the process of suberization is accelerated by high temperature and lack of moisture in the soil (Fig. 50). Large-scale suberization of primary absorbing roots occurs in the autumn and winter. Suberization does not preclude water intake but considerably hampers it—by 18 to 30 per cent—compared to unsuberized roots. Consequently, primary roots are capable of active intake irrespective of their age. Suberization of the exodermis and endodermis does not lead to the roots losing their absorbing capacity. This prompted I. A. Muromtsev to call a primary root wherever it still retains live primary cortex *an active absorbing root* to indicate its ability to take in water together with the substances dissolved in it.

I. A. Muromtsev (1963) confirmed that suberization of the endodermis is rarely complete; as a rule "permeable" cells opposite the xylem rays remain intact all along a primary root. This partly explains why suberized cells do not lose their capacity for water and nutrient intake. He established that though all permeable cells account only for 9 to 14 per cent of the endodermis surface the absorbing capacity of the suberized roots decreases but slightly. The conductive roots are only capable of little passive absorption as a result of transpiration and other factors, which constitutes their principal difference from the absorbing roots.

It should be noted that the problem of the absorbing capacity of all the four different types of roots calls for further study.

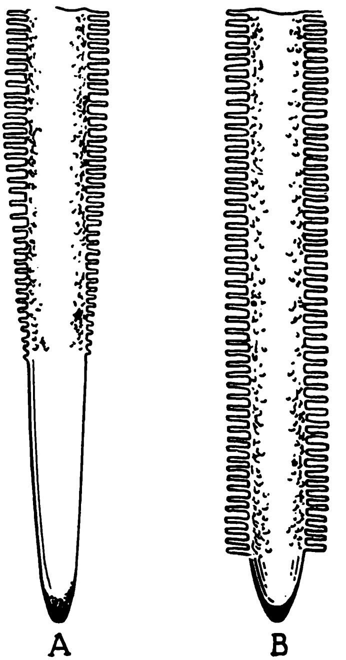


Fig. 50. Rootlets on actively growing (*A*) and in nongrowing roots (*B*) (after I. A. Muromtsev)

It should be borne in mind that the growth and development of a tree in the spring depends on the last year's reserves of nutrient substances stored up in the trunk, branches and roots. By the time leaves appear and the storage substances are used up the roots have to join in providing leaves with, first and foremost, water and nutrient substances. That is why the fruit grower must, depending on the conditions of the year and the properties of the soil, carry out such cultural practices as will ensure sufficiently vigorous growth of absorbing roots by the time of the mass appearance and unfolding of leaves.

By the use of appropriate cultural practices the fruit grower can grow a sufficient mass of active roots and also extend the period of their growth beyond the growing season and into late autumn and even winter, so that roots will grow not 4 to 5 months, but as long as 9 months and even the whole year, as e.g., in the southern zone of the U.S.S.R. in warm winters.

This is also important because active roots of the autumn-winter origin are longer-lived and richer in nutrients than the spring ones. The greater their number the more new active roots will arise in the spring. Hence it is obvious that the longer the active roots grow and the more numerous they are the easier it is for the tree to build up a large crop.

It is essential to be able to determine the condition and approximate number of absorbing roots so as to know when to stimulate their formation. Visual determination by counting the number and observing the condition of the conductive (yellow) and the absorbing (white) roots, it is a quick and sure way of getting an accurate knowledge of the vital activity of a root system at any time of the year. To achieve this a lump or a monolith from the top 30 to 40 cm of soil is taken out by a spade usually at the far edge of the tree spread and placed into a pail of water; then the earth is washed carefully away and the root nets examined, the white tips giving an idea of the total number of growing roots in the entire root system.

Aerial Portion

The rhythm and phases of growth and development. The rhythm of development means the regular succession of physiological phases during the whole life of a plant while the rhythm of a growing season means the same for one growing season. The phases of development, or phenological phases are the peak manifestations of the changes occurring in plants in connection with the appearance of new shoots from the special growing points. The succession of phases in the ontogeny occurs as a result of the vital activity of a plant and is historically conditioned by the development of and change in the vital functions of its organs (V. N. Voroshilov, 1960).

Phenological phases include such recurring phenomena in the yearly life of a plant as bud bursting and flowering, shoot growth, differentiation of fruit buds, fruit setting and ripening and the falling of leaves. With a view to a more thorough study of the life of a plant the principal phenological phases are further subdivided into periods or phases. For instance, the phenological phase of

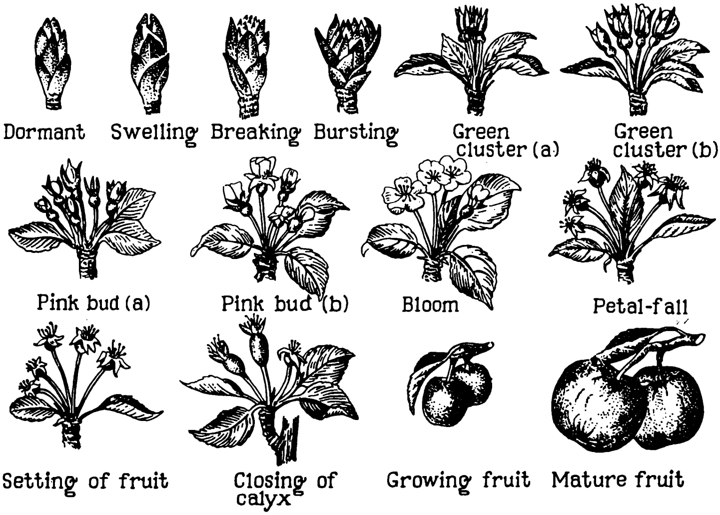


Fig. 51. Stages of apple fruit bud development

flowering is often subdivided into three phases, those of beginning, peak and end of flowering (Fig. 51).

The beginning and duration of phenological phases vary according to the inherited characters of a species, natural conditions and cultural practices.

The length of the growing season or the sum total of the phenological phases is different in different plants. The citrus and subtropical fruits have a growing season of 8 to 9 months in a year, the nuts and stone fruits 7 to 8 months while all fruit species in the middle and northern zones of the U.S.S.R. 5 to 6 months. Varieties of one and the same species, e.g., apple, pear or sour cherry, may greatly vary in length of growing season depending on the zone of cultivation.

Bud bursting and flowering. In the spring wood and fruit buds swell and burst on fruit plants. In some species, such as the filbert and almond, fruit buds burst somewhat earlier and in others, such as apples and pears, later than the wood buds. Fruit trees produce considerably more flowers than is necessary for the current crop. Apples and pears, for instance, use only 5 to 15 per cent of the total

flowering to produce a normal crop. This means that a tree possesses a capacity for creating an abundance of reserve flowers, a capacity which is biologically useful in ensuring a maximum increase in progeny. With a view to obtaining large-size fruit every year, however, the fruit grower must try, through correct soil management and tree pruning, to achieve moderate annual flowering, such as is known through experience to be sufficient for a high yield.

The time of the beginning of flowering depends on the climatic conditions. Flowering takes place when air temperature is about 8 to 12°C depending on species and variety. The beginning of flowering does not depend in any way on the root system, which is another manifestation of the phenomenon of localization in the life of a plant. The experiments conducted by D. D. Romashko (1954) in the Ukraine showed that the flowering of Pippin Litovsky began on May 5 when the soil temperature was 10.3°C while under the mulch it was only 0.8°. Yet flowering of all the trees began and continued approximately at the same time.

Apple varieties show certain regularity in blooming periods which they retain in whatever locality they are grown: (1) the early ripening varieties are on the whole characterized by early blooming periods; (2) winter and late winter varieties bloom late; (3) autumn and autumn-winter varieties are midseason bloomers. There are however certain exceptions (F. D. Likhonos, 1954).

The length of the blooming season varies according to species and variety. There are early blooming, late blooming and midseason varieties. There are rare varieties, such as Korolevskaya Korotkonozhka apple, that bloom one to three weeks later than all the others. Such varieties present great interest, for they are less liable to be damaged by spring frosts and provide valuable material for crossing and breeding new late-blooming varieties.

With the increase in elevation blooming begins approximately two days later with every 100 m above the sea level.

Beginning of the blooming season varies in different fruiting shoots. Fruiting shoots on a tree which sets its fruit buds early bloom earlier than those setting their fruit buds at a later period. Flowers open first of all on spur systems, then on individual spurs and later on yearling wood provided the buds were set in the previous year.

Apple fruit buds situated lower along the axis bloom somewhat earlier than those situated higher. Blooming on the southern side of a tree begins somewhat earlier than on the northern and in the centre earlier than on the outer edge except in sour cherries where the reverse is true.

All the cited examples of earlier blooming are explained by a greater age or an earlier development of fruit buds in the previous year.

The length of the blooming season varies greatly depending on climatic conditions. One and the same tree may have a blooming period from 6 to 15 days in different years. Fruit varieties begin to bloom in the following order, from early to late blooming: filbert and Cornelian cherry, almond, peach, apricot, sweet cherry, plum, sour cherry, pear, apple, quince, walnut, rowan tree, medlar and sweet chestnut.

Over a period of 12 years, from 1941 to 1952, in the Moscow Region apples bloomed from 12th to 30th, pears 4th to 23rd, plums 4th to 22nd and sour cherries 5th to 24th of May. When the temperature is high and stable the time of blooming is considerably shortened, yet the given order in blooming of different varieties over the years is maintained.

Growth of shoots. Crops are built up by the common effort of the leaves and roots. It is essential that every year fruit plants should have sufficiently long shoots on which big numbers of leaves can be formed. In the Moscow Region, as observed from 1951 to 1962, 12- to 17-year-old bearing apple trees had as a rule only one period of shoot growth extending from the end of May to half or the middle of July. Consequently, shoots grew for $1^1/_2$ to $2^1/_2$ months in a growing season, but active growth—from 6 to 17 mm a day—lasted only for 15 to 25 days, usually falling on June (Fig. 52).

Shoot growth in sour cherries in the Moscow Region lasts only for 35 to 40 days (V. D. Turkov, 1959). The period of deep rest in one- to three-year-old Antonovka seedlings in Poland extended approximately from mid-December to mid-February, i.e., for two months (S. Peniazek and I. Wisniowska, 1958).

The length and rate of shoot growth varies with variety, natural conditions and cultural practices. For instance, 17-year-old Antonovka Obyknovennaya apple trees in the

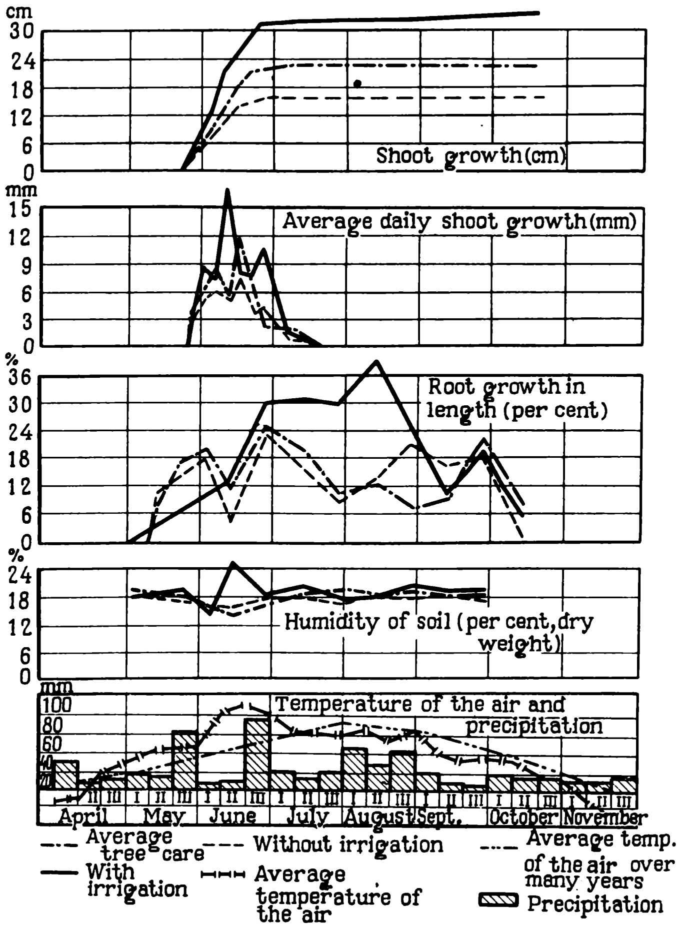


Fig. 52. Dynamics of apple shoot and root growth of Antonovka Obyknovennaya on seedling Anis. Shoot growth continued for about 2 months, with only one month (June) of vigorous growth (up to 6-17 mm per day). Root growth without additional watering was in 3-4 flushes while with irrigation it was in 2 flushes but considerably more vigorous (up to 37 p.c., instead of 24 p.c. without irrigation)

Moscow Region averaged under equal soil conditions and management 30.8 cm growth in one growing season on Doucin III, 29.2 cm on *M. sylvestris*, 26.7 cm on Chinese apple and only 20.7 cm on seedling Antonovka. It will be seen that rootstock exerts a considerable influence on scion shoot growth (N. Gena, 1959).

It has been found by the author that the average growth on 15-16-year-old Antonovka trees is 10 to 15 cm under common management, 20 to 25 cm with mulching and 35 to 40 cm when irrigated. Average shoot growth over 24 hours for apple trees in the Moscow Region was 17 mm with adequate irrigation, 11 mm with less irrigation and only 7 mm without irrigation. This goes to show clearly the effect of irrigation and mulching on shoot growth.

The longer the shoot grows the larger the leaves they have. Fifteen year old Antonovka Obyknovennaya trees, for instance, averaged 24.5 sq cm of leaves on a 50 cm long shoot and only 14 sq cm on a 11 cm long shoot on the same tree. It is essential to bear this fact in mind in fruit growing.

When shoot growth decreases, which for apples in the Moscow Region occurs approximately in the second half of June, it can not be increased, e.g., by irrigation, as in the case of roots. Apparently some biochemical and other changes, such as preparation to setting fruit buds, occur in apple trees before that time and switch their organisms over to the carrying out of other functions. July seems to mark the beginning of the summer rest period in shoot growth which later passes into the winter rest period.

Apple trees should therefore be adequately provided with moisture and nutrient substances, particularly prior to increased shoot growth, which in the Moscow Region falls on early spring to mid-June and in the south even earlier. This helps to increase average shoot growth and the length of shoots and build up large leaf surface at an earlier stage. Cultural practices should be geared to the best possible use of the rate of growth of plants and help to produce, at the earliest period of the year, new growth sufficient to guarantee high yields. New growth also ensures annual addition of young fruiting wood on a tree.

The better the roots grow in the spring and early summer the greater the shoot growth is. In the autumn extension growth occurs only in the root system. This should also

be borne in mind in carrying out the cultural practices in the orchard.

Maturing of tissues. The requirement for better wintering of fruit trees is that the wood of the entire tree and particularly that of the current growth should properly and timely mature. This is achieved if shoot growth occurs at the right time and all the parenchymous tissues have storage substances in the form of carbohydrates and nitrogen compounds. Favourable autumn weather is of importance here as well as sufficient quantities of leaves undamaged by pests and diseases.

The phenological phase of wood maturing begins as soon as vegetative growth stops. By this time the meristematic cells cease to grow and start developing into permanent tissue which will suberize and, by winter, become properly mature and frost-resistant.

Organic substances like fats, starch and others are stored in the tissues of aerial and root systems.

Only mature wood can ensure vigorous growth in the spring and adequate feeding for the flowers (F. Kobel, 1954).

The use of cultural practices such as watering, soil management, fertilizing and top-dressing, and cover crops, makes it possible to regulate both shoot growth and termination of vegetative growth in good time for the wood to mature against winter.

Leaf abscission. Most of the tree and soft fruits cultivated in the U.S.S.R. belong to the family of deciduous plants which means that they winter over in a leafless state. The other, smaller group which includes the citrus fruits and the subtropical olive, feijoa and avocado, are evergreen retaining their leaves for one to four years. Leaf abscission of deciduous trees and shrubs of the northern and temperate zones is a form of adaptation to adverse climatic conditions, notably long spells of low winter temperatures, which they acquired in the course of their evolution.

The deciduous plants have developed the capacity to terminate the formation of leaf-bearing shoots in the first two to two and a half months of the growing season so as to ensure a plant with an adequate leaf surface for assimilation. Before the shedding of leaves most of the products of assimilation in them are transported into the plant.

By studying the development of the leaf-bearing growths and yellowing and abscission of leaves of a variety in summer and particularly in winter it is possible to assess the degree of its fitness for the natural conditions of a given locality. As observed on October 6, 1957 when the temperature was —3.6°C in the orchard of the Timiryazev Agricultural Academy (four days before the frost) the Kitaika Zolotaya Rannyaya (early-summer variety) lost 98.2 per cent of leaves, Korichnoye Polosatoye (autumn variety) 36.8, Antonovka Obyknovennaya (winter variety) 25 and Slavyanka (late-winter variety) 20 per cent. This shows that the Kitaika Zolotaya Rannyaya apple is more suited to the conditions obtaining in the Moscow Region, for it requires the shortest growing season and is more winter-hardy than the others (V. I. Yakushev, 1957).

Time of leaf abscission also depends on the external factors, including cultural practices. Under adverse natural conditions and inadequate orchard care noticeable leaf shedding starts on old fruiting wood and inside the tree tops even in mid-summer. Leaves are often light yellow in colour and start falling in numbers at harvesting time. On the other hand, trees with a vigorous root and top system not only retain their leaves after harvesting is over but also have dark-green leaves. On a tree free from fruits such leaves are able to carry on photosynthesis, give a start to a vigorous autumn root growth and help the tree to store up as much nutrient substance as possible to make it winter-hardy and sure of normal spring growth.

Differentiation (Morphogenesis) of Fruit Buds

Scientists and fruit growers have long been interested in the problem of fruit bud formation and the period of this most important process in tree and soft fruits. Among the first contributions to the science of fruit biology were studies undertaken by N. I. Zheleznov in Russia (1851) and E. Askenazi in Germany (1877).

When there are no periods of low temperatures in the southern zone of the U.S.S.R., e.g., in the Crimea, or in certain substropical areas of the world like South California or Cape Province, fruit buds may degenerate and drop (Fig. 53). This explains the fact why certain fruit plants can be cultivated in the tropical zone. However,

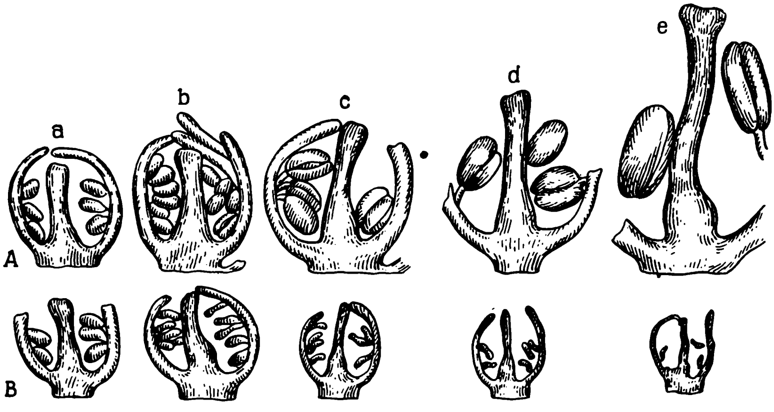


Fig. 53. Development of peach fruit buds in winter:
A—in natural conditions; *B*—at room temperature: *a*—October 27; *b*—December 31; *c*—January 31; *d*—March 1; *e*—April 1 (after L. I. Sergeyev).

certain other fruit plants, such as peach and pomegranate, may become evergreen and start bearing after several years in a tropical area which is due to deep changes in their inherited characters (L. I. Sergeyev, 1950).

As shoots grow buds are formed on their sides and tips. In some buds cell division in the growing points ceases in the autumn and they remain vegetative until next spring. In others, meristematic cell division goes on and leads to the formation of three to four layers of new meristematic cells which are easily seen under a microscope. This shows that in such buds (in apples) the vegetative activity of the growing points has almost been completed. Following this another two to three meristematic layers are formed, after which, provided the conditions remain favourable, fruit bud differentiation begins.

Meristematic cell division leads to the formation of a *vegetative cone*, in 5 to 8 or more days, which has a "swelled" look. This and the presence of three to four layers of meristematic cells serves to diagnose the beginning of fruits bud formation (I. S. Rudenko, 1960).

First *initials of bracts* are differentiated, in the axils of which primordia of future flowers are formed in the course of several days. The centre of each flower primordium becomes a concavity, on the fringes of which five sepal

12
12
12
11
12
5
6
8
6'
6''
1
2
3
4
10
12

primordia arise. Simultaneously a torus is differentiated, on whose inner surface there arise the primordia of *petals* and, somewhat later, *anthers* and, finally, of *carpels*. Thus by the end of summer or the growing season, the primordia of all the main parts of a flower are formed. Ovules are usually formed in the spring. To be more exact, archesporeal tissue develops, e.g., in plums, during a period of relatively low temperatures in December-February. Plum varieties with rapid winter growth of flower primordia form their microspores in February and the slow rate varieties in March (D. I. Tupitsin, 1955).

Fruit bud initiation begins in the summer but the actual period varies with species, variety, age and bearing, the age, position and type of fruiting wood, and the physical conditions and cultural practices. In the Ukraine and the Kuban area in the U.S.S.R., Germany and California, for instance, actual dates of the beginning of fruit bud initiation vary from June 11 to August 21 for apples (so that by mid-November fruit buds may look as shown in Fig. 54), June 21 to August 12 for pears, June 9 to August 2 for sour cherries (between June 9 and August 30 in the U.S.S.R.), June 21 to August 9 for plums and June 30 to September 17 for peaches. Fruit bud formation in nine sweet cherry varieties in Poland begins in mid-July and continues all through the winter (A. Buczek, 1961).

In Uzbekistan fruit bud differentiation begins in the early July for sweet cherries, mid-July for plums and sour cherries, late-July for Chinese plums, myrobolan plums, blackthorn, peaches and almond, late July-early August for apricots (A. S. Tuz, 1960).

Fruit buds of different ages and different stages of differentiation, depending on the termination of growth of the corresponding fruiting and growth structures, can be observed on one and the same tree.

In 1952-54 in the conditions of the Simferopol district of the Crimea the differentiation of flower primordia in tip buds on shortened shoots began in different apple varie-

◀

Fig. 54. Longitudinal anatomical section of a terminal fruit bud separated from Anise Sery fruit spur on November, 13, 1955 (in this state buds enter the period of winter dormancy):

1—initial calyx lobe; *2*—initial petal; *3*—initial stamen; *4*—initial carpel; *5*—hairs; *6*—bud leaf *6'*—bud leaf acting as a bract; *6''*—bractea; *8*—bracteolae *10*—axillary bud of replacement leader; *11*—intermediary leaf; *12*—bud scales

ties from June 16 to 20 for Napoleon, June 23 to 30 Sary Sinap, June 30 to July 7 Candille Sinap, July 3 to 7 Rosemarine blanche, July 20 to August 3 Simirenko's Reinette and July 23 to August 5 Reinette de Champagne.

Fruiting shoots begin fruit bud differentiation at different times. The earliest to differentiate are the tip buds on old shortened shoots, or spurs, then on the young ones, then on short yearlng wood and finally comes the turn of the axil buds on long yearling wood. By the beginning of October the primordia of all flower organs are usually formed (I. S. Rudenko, 1960). The same sequence of fruit bud initiation has been established for apples and pears in the conditions of Bulgaria (Stoyanov *et al.*, 1961).

Like apples many other fruit trees, such as pears, peaches, almonds, apricots, sweet cherries and plums, form buds in optimum conditions in the period between July and August. However, certain other species, e.g., the olive, begin bud differentiation only by the end of April, while the Japanese persimmon does the same in late January. The entire cycle of bud development occurs within a period of two months (K. A. Sergeyeva, 1956).

Fruit-bud differentiation in apricots begins in the Crimea in the closing days of July or in the beginning of August depending on the year's weather conditions and varietal peculiarities. The earliest differentiation is observed in the varieties of the Eastern-Asiatic group, followed by the varieties of the European and Irano-Caucasian group in that order. Differentiation is spread over a period of 50 to 80 days and continues during the winter (A. M. Sholokhov, 1961).

Each shoot has fruit buds at different stages of development. The development of fruit buds is always later on yearling wood than on spurs. The flowering stimulus is as a rule stronger in the middle portion of a shoot and weaker at the base and at the tip (O. Zeller, 1960).

According to findings of N. I. Pilipenko (1954), fruit bud formation begins two to three days after the termination of the growth of a fruiting shoot. The more northward and the higher above sea level the tree grows the later its fruit buds are formed. In droughty years fruit buds are formed earlier than in wet years.

I. S. Rudenko has established (1955) that different apple varieties form buds in similar conditions in one and the

same year within a period that varies from 23 to 30 days. This is very important for it shows that appropriate treatment, particularly feeding and watering, can help the tree manage to form fruit buds in time for the next year's crop.

In the Moscow Region buds of certain forest trees continue growing throughout January and February at temperatures not lower than —10°C (N. I. Zheleznov, 1851). Buds of certain bushes, e.g., gooseberry, grow in winter months (S. V. Viktorov, 1943). S. V. Viktorov believes that most plants have no complete cessation of growth and differentiation of buds and their tissues throughout the winter. In the middle zone of the Russian Federation fruit buds of sour and sweet cherries did not grow in winter (T. P. Petrovskaya, 1955) or, in the case of sour cherries, grew slowly (V. D. Turkov, 1961).

Quince fruit buds developed during the winter in West Germany (O. Zeller, 1960).

In the conditions of Uzbekistan development of apple fruit buds went on in winter, speeding up when it was warm and slowing down when it was cold (A. P. Zhukova, 1959), which was also true for the stone fruits (A. S. Tuz, 1960). It has been found that the rate of growth of the Central Asian and Caucasian plums, such as *Pr. salicina*, *Pr. Simoni*, *Pr. Sogdiana* and *Pr. cerasifera*, is higher than that of the European and North-American varieties (*Pr. domestica*, *Pr. spinosa* and *Pr. Munsoniana*) (D. I. Tupitsin, 1955).

Pollination, Ovary and Fruit Development

Pollination of fruit plants first assumed practical importance when fruit growers began planting commercial orchards consisting of one or few varieties. An interesting case envolving a pear plantation has been recorded in the U.S.A. at the end of the 19th century. The trouble was that though the trees appeared in perfect order and bloomed well they bore no fruit. In 1891 the plantation was examined by M. White who diagnosed self-unfruitfulness of the variety planted and recommended additional planting of other varieties for successful pollination.

Few species can bear fruit if their flowers are pollinated by pollen from the same flower, in which case self-pollination is termed *autogamy*, or from another flower on the same

plant (*geitonogamy*), or from flowers of the same variety. Such species are said to be *self-fruitful*. Most fruit plants however set fruit only when the pollen transfer is from one variety to another variety. Such varieties are known as *self-unfruitful*, or *cross-pollinated*. Cross-pollination in tree and soft fruits may occur owing to *dichogamy*, i.e., unsimultaneous maturing of anthers and stigmas in the same bisexual flower. Insects or wind may deliver mature pollen to an already mature stigma. The plants in which the anthers mature earlier are known as *proterandrous* while those with early maturing stigmas are called *protogynous*.

Cross-pollination in bisexual flowers may be also made necessary by *hercogamy* (Fig. 55), i.e., position of anthers and stigmas in the same flower at different levels (A. Osterwalder, 1910).

There is another interesting phenomenon which was observed by I. N. Ryabov (1930) on plums, peaches and almonds (Fig. 56). In certain varieties of these species stigmas and upper portions of style are pushed out at pink bud stage, long before full blossom. Certain workers have also observed the splitting of anthers in peaches before full blossom, the absence in many varieties of stamens, anthers and pistils or some defect or doubleness in flowers, and the absence or insufficient quantity of pollen in anthers.

The study of pollination has revealed the necessity of planting several varieties in an orchard to ensure the optimum pollination and fertilization of plants.

Varieties planted in an orchard for pollination purposes are known as *pollinator* varieties. They must possess certain qualities, the most important of which are similarity in bearing age and blooming period and longevity with the pollinated variety. Pollinator varieties must also produce large quantities of viable pollen.

According to the quality (germination) of pollen varieties are divided into three groups: best varieties with 71 to 100 per cent germination, medium varieties with 31 to 70 per cent germination and poor varieties with 0 to 30 per cent germination. Only varieties belonging to the first and second groups are recommended as pollinators (Fig. 57).

As a result of a thorough study of the pollen of many apple varieties V. I. Karamysheva (1961) included Boro-

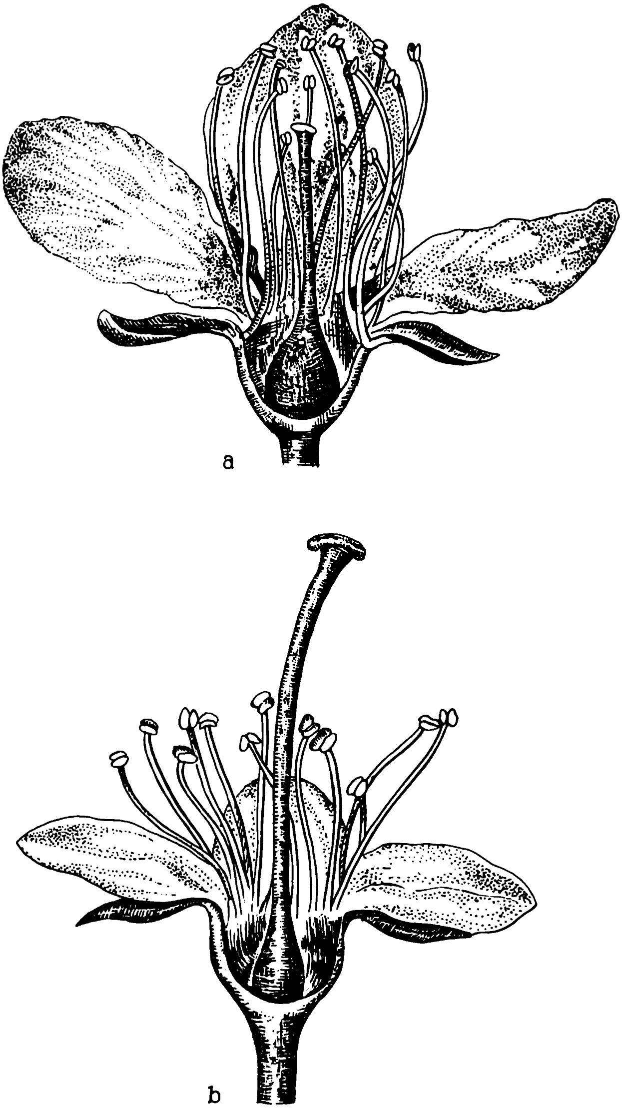


Fig. 55. Plum flower sections:
a — Wickson variety; *b* — Columbia variety (after I. N. Ryabov)

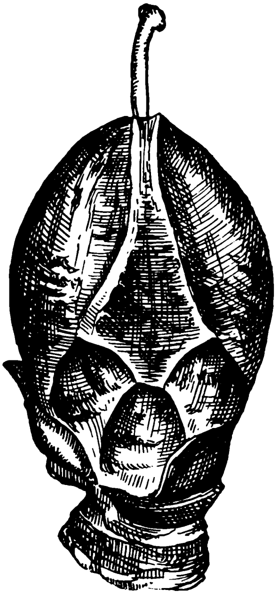


Fig. 56. Stanwick Nectarine peach fruit bud with style emerging (after I. N. Ryabov)

vinka, Grushovka Moskovskaya, Osenneye Polosatoye and Slavyanka in the first group, Anis Sery, Antonovka Obyknovennaya, Korichnoye Polosatoye and Melba in the second group and Candille Kitaika and Pobeda in the third group.

Two representatives of the nut family, walnut and filbert, are anemophilious, or wind-pollinated, while all the other fruit plants are entomophilious, or pollinated by insects, mostly honeybees, but also by bumble bees and some wild bee-like insects. It is usual to have beehives in the orchard. A single bee may carry up to 100,000 pollen grains on its body (N. F. Childers, 1947) (Fig. 58).

O. I. Misterhaze (1961) found that apple flowers visited by bees ten times give 5.6 times more fruit set than those visited once. The average weight of Bely Naliv apples with all the five stigmas pollinated was 11.9 per cent more than that of fruits with only one stigma pollinated. The percentage of apples with a maximum number of seeds increased from 4.4 to 78.5 depending on the number of pollinated stigmas. The increase in the number of normal seeds was associated with an increase in the weight and size of apples and with their better taste.

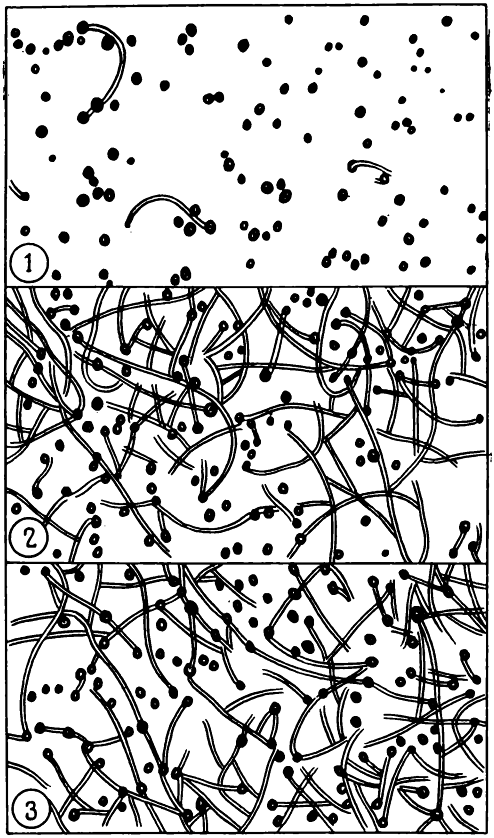


Fig. 57. Pollen germination:

1 poor; *2*—medium; *3*—strong (the best pollen)

The pollen grains of the wind-pollinated plants are small, round, dust-like, with a smooth surface pierced by one or two pores. The slightly bigger pollen grains of the insect-pollinated plants are sticky, round, with small projections on the surface.

Each anther in apples contains about 3,500 pollen grains, and since there are 20 stamens, this makes 70,000 grains per flower (N. F. Childers, 1947).

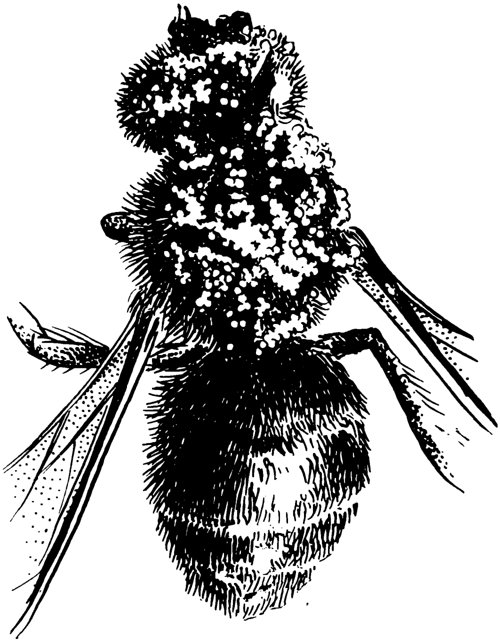


Fig. 58. Honey bee after visiting several flowers. Note numerous pollen grains sticking to its body

For successful fertilization fruit plants require optimum conditions as regards warmth, light and humidity. The processes of pollination and fertilization are adversely affected by low (0.6 to 2.2°C or lower), as well as high temperatures (30°C or over), and also by rainfall, fog, wind, and the overall unfavourable climatic conditions at the time of blooming.

Fertilization is also hampered by pests and diseases damaging pistils and stamens.

N. D. Patanina and V. N. Shmigel (1960) established that treatment of fruit tree pollen in an electrostatic field generated by direct high-voltage current (12 kv/cm at 10 sec. exposition) increased its germination vigour and the length of the pollen tubes. Pollination by such treated pollen brought about better setting of fruits, increased their average weight, number of viable seed and their absolute weight.

Between pollen and stigma exists a rather complicated interrelation. The decisive factors of germination are the secretions of the stigma at the time the pollen tube grows down the style and the conditions resulting from interaction between those secretions and the pollen.

Stigmas can be pollinated during 6 days in stone fruits, 7 days in soft fruits and 9 to 10 days in pome fruits, being most receptive on the third to fourth day for all fruit plants except raspberry, whose best period is the second to third day (E. P. Sokolova, 1953).

To guarantee normal pollination fruit plants should be interplanted and provided with honey bees at the rate of one to two hives per hectare.

Apple and pear. Most apple and pear varieties are self-unfruitful. When self-pollinated they set few or no fruit. There are also varieties that are cross-unfruitful, or physiologically incompatible. Investigations conducted by L. M. Sergeyev (1952) at the Krasnodar Fruit- and Vine-growing Station revealed a number of cross-unfruitful combinations, such as Simirenko's Reinette × Rosemarine blanche.

I. N. Ryabov (1953) in the Crimea has found the best combinations of three to four apples and pears for interplanting in the south, e.g., London Pippin, Reinette de Champagne and Simirenko's Reinette for apples and Beurré Bosc, Olivier de Serre and Williams' bon Chrétien for pears.

Quince. There are self-fruitful, partly self-fruitful, and self-unfruitful quince varieties.

Cherry. All sweet cherry varieties are practically self-unfruitful. Sour cherries may be self-unfruitful, self-fruitful and partly self-unfruitful. Hybrids between sour and sweet cherries, known as Duke cherry are mostly self-unfruitful. There is a certain amount of cross-unfruitfulness among both sour and sweet cherries. In the Crimea there are mutually fruitful and simultaneously blooming cherry varieties such as Gaucher and Bigarreau Grolle, and Yellow Denissena and Yellow Drogana.

Plum. Plum varieties are divided into self-fruitful, self-unfruitful and partly self-fruitful varieties. The varieties belonging to the group of *Prunus salicina* Lindl. are mostly self-unfruitful; those of *Prunus americana* Marsh. are self-unfruitful and partly self-fruitful; those of *Prunus domestica*

Thunb. are self-fruitful and self-unfruitful; and those of *Prunus insiticia* Fries. are self-unfruitful. Cross-unfruitfulness is common among plum varieties.

Apricot. There are self-fruitful (most European varieties) and self-unfruitful (Asiatic varieties) of apricots.

Peach. Self-fruitful with the exception of a very few varieties which are self-unfruitful.

Almond. Mostly self-unfruitful with a few exceptions which are self-fruitful. Some varieties show cross-unfruitfulness.

Filbert. The trees are monoecious and the flowers unisexual. Self-unfruitful varieties predominate.

Walnut. The trees are monoecious and the flowers unisexual. Most varieties are self-unfruitful.

Pecan. The trees are monoecious and the flowers unisexual. There are self-fruitful and self-unfruitful varieties. They are divided into three groups according to the blooming period: (1) female flowers open after blossom fall in the male ones, (2) blossom fall in female flowers by the beginning of blooming in the male ones, (3) blooming of female and male flowers roughly coincides. Varieties should be interplanted including several varieties (T. K. Kvaratskhelia, 1962).

Pistachio. Dioecious and unisexual. Interplanting is required of female- and male-flowered trees.

Chestnut. The trees are monoecious, flowers unisexual, varieties cross-fruitful.

Olive. Varieties are divided roughly into two equal groups self-fruitful and self-unfruitful, and therefore, like pome fruits, have to be interplanted.

Fig. A dioecious plant. Some plants bear inflorescences with female flowers which after fertilization produce edible fruit, while others have only male inflorescences producing inedible fruit known as caprifics; these serve as pollinator trees. Pollination is effected by insects blastophages which develop in the male inflorescences, fly out of them covered with pollen grains and fertilize the female inflorescences. Many varieties set fruit without pollination.

The fig yields two crops in one summer. Its flowers are inflorescences concealed in a curved hollow torus with a small orifice at one end. After pollination—and in many varieties without pollination—the inflorescence grows into a juicy edible sorosis. In fig plantations 5 to 6 pollina-

tor trees are planted per one hundred edible fruit trees or alternately from 20 to 60 or more caprifics are hung on every tree for pollination.

Persimmon. Dioecious and monoecious plants; sometimes female and male flowers are found on the same plant. The persimmon is able to crop with and without pollination but the fruit differ in quality besides being seedless in the latter case. It is normal practice to plant 10 to 12 pollinator plants per one hundred trees.

Pomegranate. The flowers are divided according to the shape of the pistil and period of blooming into two groups: (1) the bell-shaped, short pistillate which are underdeveloped and (2) the ascidiform, long-pistillate which are normal. The first to appear, on last year's wood, are flowers of the second group. After that first-group flowers begin to bloom, usually in great profusion, followed by another generation of second-group flowers, this time on current year's growth. The second-group flowers of the first blooming period are the most valuable because almost all of them bear large, first-quality, early fruits. The same type of flowers blooming later on the current growth yield smaller fruits, poorer in quality, for they are not able to ripen in good time and are affected by lower temperatures and the advent of autumn frosts.

The better the tree care the more long-pistillate productive flowers appear on a pomegranate bush.

Feijoa. The varieties are divided into self-fruitful and self-unfruitful and so require interplanting.

Citrus fruits. Varieties are divided into self-fruitful, cross-fruitful and parthenocarpic, i.e., requiring no fertilization.

Soft fruits. The Hautbois is a dioecious plant with diclinous flowers. The strawberry is a monoecious plant, but a number of varieties carry underdeveloped pistils and, consequently, are poor croppers. Raspberry is divided into self-unfruitful and self-fruitful varieties. Gooseberry and currants are self-fruitful. All soft fruits require interplanting.

To sum up, almost all peach varieties and some varieties of sour cherry, quince, apricot, plum, gooseberry, strawberry are self-fruitful, i.e., they are able to produce a commercial crop even when one variety is planted in a block. On the other hand, all sweet cherry varieties and most of apples and pears are cross-pollinated, for them to produce a

crop different varieties should grow in one plantation or orchard. All self-fruitful varieties, however, crop much better if they are interplanted with other varieties, so that cross-pollination is ensured.

The best way to select both pollinated and pollinator varieties is to consult a standard fruit growers' manual which provides characteristics of commercial varieties and their most successful combinations in planting.

Certain varieties of pears and, to a lesser extent, apples are able to crop without pollination and fertilization. This is due to the fact that their flowers can set fruit with no seed. The pericarp, i.e., the edible part of a fruit, of such ovaries develops into a fruit of normal size. The seedless fruit obtained are known as parthenocarpic while the phenomenon is called parthenocarpy.

The following apple and pear varieties with a tendency for parthenocarpy have been established for the Crimea: Candille Sinap, Sary Sinap, Napoleon, Winter Golden Pearmean and Reinette de Champagne; Williams' bon Chrétien, Curé, Beurré Bosc and Beurré Ligelle for the pear (V. A. Kolesnikov, 1927).

Metaxenia, or xenia of secondary order may be observed in fruit plants. Some workers advance an opinion that fruits may receive characteristics of the father organism. This may be observed in the changed colour, waxy surface, displacement of the core and some other characters of the fruit (V. A. Kolesnikov, 1927).

Ovary development and causes of dropping. Ovaries are noticeable even before the flower is fertilized. After fertilization they start to swell and in a period of one to five months they become ripe fruits. At blooming time when pollination occurs a heavy drop of blossoms and ovaries takes place. Ovary drop is particularly heavy in the spring and early-summer periods. This is normal if enough ovaries are left for a good commercial crop and abnormal if too many ovaries drop with a resultant poor crop.

Flower and ovary drop according to M. I. Dorsey (1919) is due to three main causes and consequently occurs in three waves in a season, between which it either weakens or even ceases.

The first wave or drop period occurs in the blooming period and involves flower drop. Some parts of such flowers, particularly pistils, are underdeveloped or altogether ab-

normal, both morphologically and anatomically; this is more common for stone fruits than for any other species.

The second wave begins a week or two after petal fall and lasts for one or two weeks. Ovary drop in this case is due to the lack of pollination or pollination by incompatible pollen.

The third wave begins two weeks after the second. It is known as "June drop" during which fertilized ovaries drop since because of various reasons they are unable to stay on spurs and develop until harvest. This drop may be quite heavy in some varieties and continue until harvest time. It is caused by the lack of fertilization and small numbers of seeds in fruits as well as by poor tree care, particularly feeding.

W. H. Chandler (1957) gives more complete data about the reasons of flowers and fruit drop in apples, particularly in the first wave the flowers drop along with unfertilized ovules. In the second wave flowers drop after pollination and there is observed a little growth of ovary and endosperm and a weak development of ovules. In fruits, held up a little longer—up to the third wave—the endosperm and ovules were still more developed. By the time of the fourth wave the endosperm was fully developed and the ovules, too, developed considerably, though not so much as in the case of undropped fruits, and they had developed less seeds per fruit.

In the Ukraine the first drop period resulted in 41.6 to 57.2 per cent of flower loss in Borovinka, Grushovka Moskovskaya and Pippin Litovsky apples and 80.9 to 91.4 per cent in Antonovka Obyknovennaya and Calville Snezhny. The first period usually began 5 to 7 days after full bloom and lasted for 6 to 12 days. The second period began three to four weeks after full bloom and continued for two to three weeks. The third period occurred during fruit ripening. Some varieties, such as Pippin Litovsky and Grushovka Moskovskaya, lost over 60 per cent of flowers and ovaries and carried only 37 to 40 per cent into harvest time (Ya.D.Romashko, 1954).

In the Crimea, according to the author's findings, Reinette de Champagne, Winter Golden Pearmain Zimny Zolotoy, Sary Sinap and Rosemarine blanche apples retained fruit only on 23 to 78 per cent inflorescences and only 4.5 to 28.8 per cent of flowers set fruit. This is common to many

apple varieties as well as to other fruit plants. In Tajikistan, for instance, the average number of productive flowers for 20 Central Asian varieties of apricots was 8.4 per cent and for 27 European and North-American varieties 19.7 per cent.

There are varieties which lose most of their flowers in the first drop period and then largely retain their ovaries and fruit till harvest time. These are the best varieties which furthermore have a greater tendency for annual bearing.

Only about 5 to 10 per cent of blossoms develop into fruits on a full-blossoming apple or pear tree.

As a rule, under similar conditions, the greater the number of seeds in a fruit, the stronger its hold on a tree, and the more uniform in shape, size and colour it is.

Using the technique of chromatography on other extracts of apple seeds L. G. Luckwill (1953) isolated four different auxins, three of which are acids and one a neutral compound. L. G. Luckwill concluded that apple fruit growth is regulated by several auxins, one of which regulates the growth of fruit, the other fruit drop, while a third influences seed growth.

A close correlation between the rate of growth and ultimate (maximum) weight of fruit and the productive leaf surface has been established. This is quite natural because after all the mass of fruit consists of carbohydrates produced by leaves. From this follows that the greater the leaf surface per fruit the bigger and better-quality the fruits are. This has been borne out by numerous studies in different fruit-growing zones and is particularly true for apples. Healthy leaves are also extremely important in preventing fruit drop. That is why it is so important to try to retain as many leaves on a tree as possible and safeguard them against attack of pests and fungi.

The younger the spur, and the thicker and longer its last growth with a fruit the least likely is the fruit to drop. In general, the better the feeding of the whole tree, particularly in nitrogen, during blooming, the greater quantity of ovaries is retained and develops into fruits.

At present research is being pursued in the U.S.S.R. and other countries on the use of various growth stimulators to prevent excessive ovary and fruit drop on fruit plants.

Growth and development of fruit. At first an ovary is an insipid mass of tissue. Then gradually as its morpho-

logical, anatomical and physiological qualities undergo a change it develops into a fruit which can lead an independent life on a tree and even after being harvested; fruit of most varieties can keep for 5 to 10 months in an ordinary fruit store while fruit of such apple varieties as Sudaksky Sinap in the Crimea and Kekhura in Georgia can keep for more than one year.

The following biochemical processes involving carbohydrates take place in ovaries and then fruits: (1) transfer of sugars from leaves into ovaries, (2) transformation of sugars into starch which is accumulated in unripe fruit in fairly great quantities, (3) transformation of starch in ripening fruit back into sugar, (4) consumption of sugar in the process of respiration of fruit, particularly in storage.

The process of fruit ripening from the chemical angle is rather similar in most fruit plants and constitutes the closing stage of the development of fruit on the tree. Fruit ripening involves changes in the chemical composition and anatomical structure of a fruit. The principal chemical changes involve carbohydrates, pectic compounds and tanning substances. The flavour of a fruit is mostly determined by its sugar-acid ratio.

The fruit of most varieties contains the malic and citric acids. As a fruit grows and ripens, the amount of acid in it is reduced. The accumulation of sugar continues while the fruit ripens on the tree and—in winter varieties which usually still retain some starch at harvest time—for some time after it is harvested.

Sugars vary in chemical composition and time of formation. At first they are stored up as glucose, then as fructose—the sweetest sugar—and later as sucrose.

The pectic substances which include the protopectin part of the tissue of cell walls, the pectic acid and the soluble pectin are all complex organic compounds. They gain a high degree of concentration during ripening after which they undergo modifications and are reduced in quantity.

The tannic substances which are stored in considerable quantities, notably in medlar, quince, persimmon and pear, impart astringent quality to fruit.

As a fruit ripens its physical condition and anatomical structure change. The protopectin—the backbone of intercellular layers—is transformed into soluble pectin due to which fruit tissues toughen until they mollify and certain

substances change to ethers. As a result the toughness of skin and flesh is much reduced and the fruit acquires taste and aroma.

The chlorophyll in the cells of the skin decomposes and yellow and red pigmentation appears. The seed in the fruit assumes brown colour, the calyx dries up, the fruit-stem becomes slender, abscission tissue develops between the fruit-stem and the fruiting branch and the fruit, if not harvested drops down.

The harvested fruit is an organism which spends sugars and acids for its metabolic processes and water for transpiration. In six and a half months apples stored at a temperature of +2°C lose 33 per cent of their sugars on respiration and 45 per cent at +7°C. They spend least sugar and are stored for the longest time at temperatures of 0 to —0.5°C. At reduced temperature fruits preserve their flavour and morphological qualities longer.

Growth and Rest Periods in Plants

Certain periodicity can be observed in the process of growth and development of fruit plants throughout the year. A period of heightened vital activity is followed by a period of relative rest. In the conditions of temperate climate the periodicity of growth and rest is closely connected with the adverse conditions of summer drought and winter cold.

Two main periods in the yearly life cycle of fruit plants are commonly recognized: (1) period of vegetation and (2) period of rest.

The period of vegetative growth is manifested by growth and development of branches and roots, by blooming and bearing.

Conversely, the period of rest is manifested by no outward sign of plant life. Indeed rest is an adaptation of a plant to tide over in adverse conditions which was developed in the process of evolution and fixed in heredity. Rest, after N. A. Maximov, is a state of the development of a plant.

The blooming of temperate-zone perennials occurs at the normal time only on condition that they had low temperature—below 5°C—for a sufficiently long time in the previous winter.

Strawberry, for instance, requires 40 to 50 days for its rest period while for apples and pears it is 50 to 60 days depending on the variety. If a temperate-zone plant receives fewer days with a temperature 5°C below that required or if the temperature is higher than 5°C all the time as is the case in the south of the U.S.S.R., in the subtropical belt, bud burst and blooming is retarded.

Cases have been recorded of a late spring causing a delay in blooming of up to 24 days while for greenhouse plants —if air temperature was not lowered in winter—the delay may be as great as 100 to 140 days.

At a very high temperature—above 20°C—temperate fruit trees can not pass through the period of rest and do not bear at all (V. P. Popov, 1939, V. R. Gardner, 1952). Sour cherries, apples, pears and other fruit trees require a winter drop in temperature failing which flower initials in buds die without resuming growth; and even if some varieties do have flowers and even fruits the latter are coarse and woody and taste worse than on trees which wintered in the low temperature conditions.

Frost resistance in fruit trees also depends on whether the tree has passed through the period of rest. Distinction is drawn between enforced and organic, or deep rest. Enforced rest in plants is due to the lack of conditions favourable for growth. But as soon as the conditions change for the better growth is resumed.

In spring, trees are ready for vegetation for they have passed the period of deep, or natural rest, but if spring is late, i.e., optimum air temperature has not set in, bud development and blooming may be delayed by one to three weeks. If a tree or branches cut from it are placed in favourable conditions in November or December when they are still in deep rest their buds will not start to grow.

But if the same tree or its branches are placed in favourable conditions in January or February when they have completed their period of deep rest and are in the period of enforced rest their buds will open relatively soon.

Until the mid-nineteenth century it was generally accepted that the arborescent plants experience a period of absolute rest in winter and that in spring they resume their growth right from where it was stopped in the previous autumn. N. I. Zheleznov was the first to establish in 1851, after measuring and weighing fruit buds in an exhaustive

series of studies, that during winter shoot primordia are formed in buds and various parts of the flowers increase in size.

Later it was found by S. V. Victorov (1943) that during the rest period the arborescent plants are the seat of the following processes: stored substances undergo transformation which is evidenced in a periodic change from a maximum to a minimum content of starch, sugar and oil; water transport goes on along with transpiration, particularly through leaf scars and buds; breathing is somewhat reduced or, according to N. A. Maximov (1958), very much reduced, e.g., in trees it is 1/200th of normal breathing as observed during the growth period; growth of various parts of fruit buds continues.

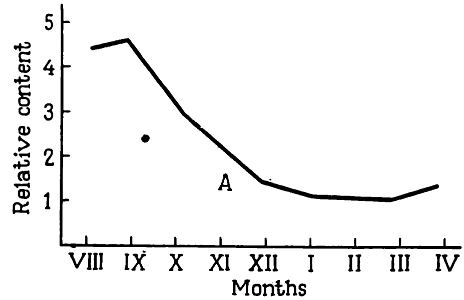
Throughout the year the content of nutrient substances, particularly of carbohydrates and nitrogen compounds greatly varies in a fruit tree. According to K. M. Poplavsky (1950) the branches and roots of 12 apple varieties showed two maximums of starch content in the course of one year, in spring before blooming and in autumn by the end of leaf fall, and two minimums, in summer at full blossom and in winter, between late December and early March. The same is roughly true for overall nitrogen content in plants.

According to findings by T. P. Pyetrovskaya (1955) accumulation of fat in sour cherry shoots is characterized by a one-peak curve. The sour cherry, as a not very frost-resistant species, accumulates less fat than the more frost-resistant fruits (Fig. 59).

Trees have the greatest amount of nutrient substances in autumn, after the shedding of leaves and the termination of root growth, i.e., in November-December. This amount is somewhat reduced during winter, then drops sharply during blooming period and even more so after vigorous tree growth in the spring. Aknowledge of this regularity will help the horticulturist to influence the passage of phenological phases in the aerial portion and the root system of a tree.

Let us consider in greater detail the biological and biochemical peculiarities of the two periods in the life of plants—those of growth and rest.

P. G. Schitt (1940), who thought it important to give a more detailed analysis of the life activity of fruit plants, introduced two more periods—transition from growth to rest and transition from rest to growth.



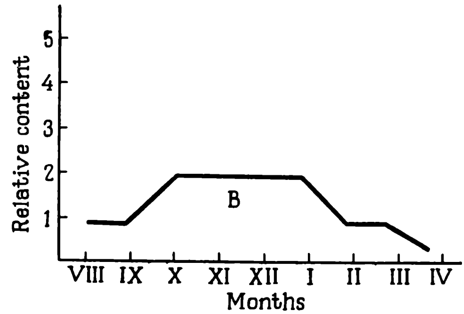


Fig. 59. Changes in reserve starch (*A*) and fat content (*B*) in sour cherry shoots during the period of relative rest; (after T. P. Petrovskaya)

Below are the main features of the four periods including those added by the author.

The first period of vegetative growth is the longest and attended by the greatest number of visual changes in a fruit tree. During this period a tree blooms, is covered with leaves, forms fruit and wood buds; vigorous root growth falls on this period too, particularly in spring and early summer.

When growth begins, a plant contains the maximum amount of starch and nitrogen compounds, which, following considerable root and shoot growth and blooming, are almost used up (by mid-June in the middle belt of the Russian Federation). It is most essential therefore that by spring, i.e., by the moment the first leaves appear, the required number of active roots have been formed to begin their vital activity in conjunction with the leaves.

Active root formation is encouraged by good soil structure and air moisture regime and by adequate plant feeding. In certain cases, e.g., with excessive rainfall in spring, a fruit grower has to take special measures to aeriate and warm the soil by loosening it, which improves conditions for active root growth and increases the water and nutrient supply to the leaves. In irrigated areas cleaning and deepening of ditches is resorted to morder to lower the ground water table and so reduce moisture in the root-inhabited layer of the soil. Orchards should not be irrigated in wet springs.

Starting with the middle of summer when tree growth is reduced or terminated while leave continue assimilation starch accumulation in shoots, spurs and fruits is greatly stepped up. As shoots become woody the tree prepares for transition to deep rest and to the autumn-winter hardening of the tissues above the ground. The activity of the root system is somewhat (sometimes greatly) reduced.

The second period is a period of transition of the aerial portion of a plant from growth to the hardening of tissues and the winter stability. This period includes the termination of lignification of tissues of the aerial portion. Sugars are vigorously transformed into starch and, apparently, into fats. Starch accumulation in fruit plants is reduced to its minimum. By the beginning of the third period, particularly when conditions are favourable (irrigation and sufficiently high temperatures), a considerable part of starch is transformed into sugars (Fig. 60), which ensures winter resistance in fruit trees.

It is common during the second period to observe vigorous growth in absorbing roots until stable frosts.

This period of activity of the absorbing roots can be prolonged by the appropriate cultural practices: manuring, mulching and snow retention, which all help to keep the required temperature in the root-inhabited layer of the soil. In other words, the second maximum of the accumulation of nutrients in fruit plants can be increased.

Adequate autumn root growth helps to stock sufficient quantities of moisture which also contributes to better winter hardiness and resistance to desiccation. This makes a case for the advisability of moderate irrigation of orchards in autumn, early winter and even mid-winter, down in the south.

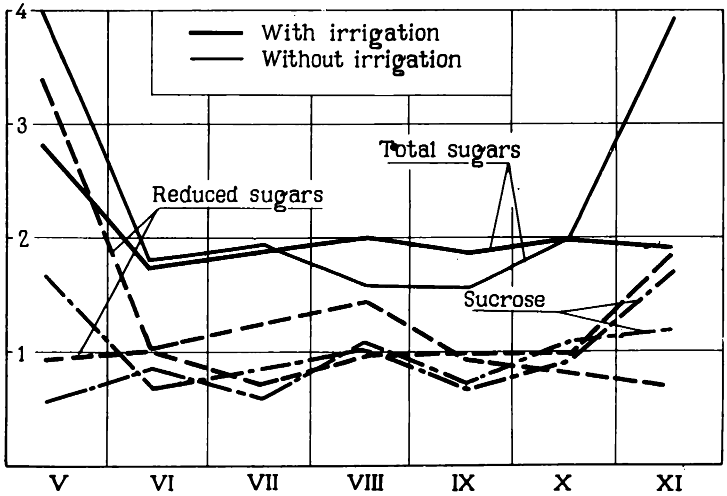


Fig. 60. Sugar content in an apple root net (in percentages of dry matter); (after Kolesnikov, 1959)

The author thinks it worth while to cite the views of P. K. Ursulenko (1936) who advocates good tree care and irrigation for fruit plants in the second half of summer. P. K. Ursulenko believes that the rest period is an adaptive reaction of plants to the unfavourable external conditions in the autumn-winter period. The transition from growth to rest in fruit plants is a highly important ability acquired in the course of evolution. Since fruit trees enter the rest period in the second half of the summer and cannot resume growth again, there is no ground for the misgivings sometimes voiced that "increased moisture and good feeding can bring about renewal of growth and the resultant lack of ripening and maturing of wood". Giving in to these misgivings many workers have repeatedly recommended lowering the level of tree care in orchards starting with the second half of the summer, particularly as regards soil moisture.

The author holds that after the harvesting of winter varieties apple orchards should be given fertilizer and irrigation, e.g., in the Moscow Region at the end of September. G. Friedrich (1958) recommends watering orchards only before frosts which is apparently advisable in the conditions

of the GDR where it is warmer and there is more moisture than in the Moscow Region.

The third period—that of the relative rest of fruit plants —is equally characteristic of the parts of a tree above and below the ground.

In this period, in the cool or cold winter months, starch almost completely disappears from plant tissues and is replaced by sugars and partly, perhaps, by fat substances (W. H. Chandler, 1957). By this period a tree has already built a big store of water and nutrient substances. Roots are active in the conditions of warm winters in the south, while in the middle belt their activity in the top 40 cm may continue into December or even longer, especially in deeper soil horizons, which ensures certain replenishment of the store of water and nutrients. All through this period water is constantly spent through the covering tissue, or peridermis of the stem and branches and through leaf scars and buds, notably on branches.

With strong winds in winter water transpiration is high in fruit trees. This may lead to desiccation and killing back of branches and even death of the whole tree, particularly after a dry autumn and no irrigation. It is essential to provide good tree care, irrigate orchards during the growing season and in the autumn in dry years and plant orchard shelters. The heavier harvest was obtained the better tree care is needed.

The fourth period is that of transition from the winter condition of relative rest to the spring-summer condition of vital plant activity. This period is characterized by poor or no growth of the absorbing roots while the aerial portion of the tree enters the growing phase. In this period the aerial portion is supplied by water and nutrients which have been stored up in the fruit tree, particularly in the previous autumn. The better a fruit plant is supplied with water and nutrient substances in the autumn the better plant growth in the spring will be. This also helps to realize a close interrelation between the individual periods in the yearly life cycle of plants.

Armed with the knowledge of the peculiarities of the vital activity of the aerial portion and the root system throughout the year the fruit grower is able to influence it in his endeavour to obtain heavy yields regularly.

CHAPTER SIX

•

BIOLOGICAL FACTORS OF TREE AND SOFT FRUIT PROPAGATION

Biological Peculiarities of Seedlings, Grafted or Budded, and Own-Rooted Plants

Methods of propagation. Two methods of propagation of tree and soft fruits are known: *sexual*, and *asexual*, or *vegetative*. Sexual propagation is mostly used with the aim to obtain new varieties by hybridization while asexual propagation is used to increase planting stock.

In sexual reproduction the male and female gametes fuse in the ovule to produce a zygote which gives rise to a new plant organism. Sexual propagation is used in breeding work to obtain hybrids or new varieties, which, if proved to be of commercial value, are then increased vegetatively as new varieties. Sexual propagation is also extensively used to grow rootstocks on which cultivated varieties are grafted or budded.

Vegetative propagation—by cuttings, layers, division, grafting and budding—is the principal method of increasing commercial planting stock of all tree and soft fruits.

As a rule cultivated fruit plants are clonal plants. Clones are plants produced vegetatively from one original parent, one branch or one bud. Clonal selection of tree and soft fruits has been used since ancient times as a means of long-term improvement of both old and new varieties.

According to W. H. Chandler (1957), the clonal variety is the most useful unit in fruit growing. A full realization of the significance of the clone as the only reliable unit in a thorough study of orchard plants is indispensable to the tackling of horticultural problems with any measure of success.

Clonal plants of one and the same variety may differ considerably depending on the age or more correctly the age period of the plant which provides the propagation material and on the part of the plant it was taken from. If the cut-

tings, buds or shoots have been taken from parent plants which are in the juvenile period, that is from young seedlings, they can under the influence of environmental conditions diverge from one another in their inheritable features and so grow into distinctly different plants.

If, as is more often the case in orchard practice, the cuttings or buds have been taken from a parent plant in the period of maturity when it is genetically stable, the resultant plants will be relatively uniform in their inheritable features (I. V. Michurin). Fruit growing practice records cases of certain apple varieties, such as Winter Golden Pearmain, Antonovka Obyknovennaya, Sary Sinap and Anis Polosaty, which have been in cultivation for several hundred years.

Vegetative propagation predominates in modern orchard practice. As a rule cuttings or eyes are taken for grafting or budding from plants which are in the productive period of their development. This is also true for stem cuttings taken for rooting. In the case of grafted or budded plants their root systems are as a rule those of a seedling, i.e., they are young, while in the second case the root systems are the plants' own, i.e., they are old.

The above mentioned peculiarities of clones, i.e., of fruit plants produced vegetatively, should be borne in mind in orchard work.

Fruit trees are generally propagated by grafting or budding and that means they have the root system of the seedling, or stock, on which they have been worked. They are usually known as budded or grafted plants. Soft fruits and some fruit trees are as a rule grown on their own roots, without the use of stock, and are commonly referred to as own-rooted plants.

Own-rooted plants are propagated by vegetative parts—cuttings, including root cuttings, layers, and root suckers—and include all soft fruits, certain varieties of sweet and sour cherry and plums, some citrus fruits (lemon) and subtropical fruits, e.g., the olive and fig.

Plants obtained by rooting portions of their shoots or roots have their own roots. The main advantage of the vegetatively propagated plants over those propagated by seed is that the new plants keep very much closer in all their characters to the parent organism. The disadvantage of vegetative propagation lies in the fact that if it is applied

Fig. 61. Root suckers of own-rooted Yandykovskoye apple tree

to an old organism over a very long period of time it may lead to varietal degeneration. In case of sexual reproduction the new plants possess a broader genetic background and are in no danger of degeneration.

Instances of very long own-rooted cultivation of apples are known in the Volga area (Fig. 61) and sweet cherries in Moldavia. In the case of Winter Golden Pearmain and Antonovka apples and notably sour cherries and plums, it is a general practice. This testifies that degeneration is indeed a very slow process and that there is no need to object to vegetative propagation on that account.

Own-rooted plants have both positive traits, such as early cropping, vigorous branch growth and regeneration (which makes it possible for plants to restore themselves after severe frost damage), and negative traits, notably a shallow distribution of the root system. It should be mentioned here that the own-rooted plants of certain varieties, particularly of pome and stone fruits, may differ consider-

ably from the grafted or budded plants in growth vigour, size of tree, start and size of cropping, size of fruit, etc., which all has been insufficiently studied and taken account of in fruit growing.

Biological Fundamentals of Vegetative Propagation

According to Charles Darwin's theory of evolution, the individual organs and parts of a plant constitute a single interconnected whole that has been evolved over centuries as a result of the interaction of organism and environment. This interaction may be termed a correlative relationship, inheritable according to I. V. Michurin, which he widely used to breed new forms and varieties of tree and soft fruits. As has been said earlier investigations have shown that there is extensive interdependence in plants between the root system and the aerial portion, which affects their growth and development and, notably, the synthetic activity in them. There are scientists who believe that external stimulation of one organ of a plant is quickly passed to its other organs. This response of organs to changes in external conditions is due to sensitivity, or irritability, inherent in every live plant organism (I. Gunar, 1953).

Despite the fact that a plant is a single whole there is room in it for localization, as has been mentioned earlier, as well as a capacity of individual parts to develop independently after their separation from the parent organism (regeneration). In tree and soft fruits, for instance, root and stem cuttings or layers separated from them will root in certain conditions and give rise to independent plants—which has been used by man since time immemorial. It has also proved possible to separate a bud or cutting and graft them on a plant—rootstock or seedling—and grow a new tree. These methods of propagation are called vegetative, i.e., propagated by vegetative parts of the parent plant.

Plants propagated by any of the vegetative means retain their varietal characteristics in relative purity while sexual propagation will always produce hybrid plants which carry characters of both parents.

Yet in this the heteronomy of different parts of shoots used in vegetative hybridization should not be overlooked. In this connection I. V. Michurin (1934, 1948) wrote, "Bear-

ing in mind the appearance of bud spurts it becomes obvious that even vegetative means of propagation of fruit trees do not at all guarantee us against difference in fruit from trees of one and the same variety in one and the same orchard. A similar picture is observed in soft fruit propagation of raspberry, blackerry, currants and gooseberry which is increased solely by vegetative means often resulting in individual plants being either extremely bad croppers or producing fruit considerably smaller than the parent plants." As found by M. V. Rytov (1896), sucker growths close to the stem of a shrub produce plants quite dissimilar to those arising away from the stem.

The capacity for vegetative propagation varies with plants. It depends on their origin, the part of plant used, method of propagation, level of nutrition, environmental conditions and the plant's ability for regeneration. Regeneration of plants or their parts is an inherited capacity and, as heredity is changed, the capacity for regeneration changes too. Consequently, the processes of regeneration depend on environmental conditions as well as on the internal conditions of the organism. An important factor here is the age period of the parent plant from which cuttings are taken.

This was observed a long time ago by I. V. Michurin who found that "the younger the seedling hybrid the easier it roots and, conversely, cuttings from old trees are poor rooters".

Cuttings separated from plants in the juvenile stage tend to root and graft better than cuttings from mature plants (F. Passeker, 1940). R. Fritzsche (1948) proved experimentally that any seedling apple is able to form roots on shoots etiolated by banking up provided it is in the juvenile stage. He believes that some of the vegetatively propagated apple rootstocks are nothing more than fixed juvenile forms. As they are invariably increased by cuttings, i.e., they are cut back to the juvenile form zone, they are preserved in the juvenile phase. If we allow East Malling root stocks, for instance, to grow into mature trees they will behave as seedlings for a few years and then turn into the bearing form.

A number of workers have convincingly proved that the younger tree and soft fruits have a more vigorous shoot growth and because of this their longer shoots possess a

greater capacity for regeneration and growth than those of older plants. R. Kh. Turetskaya (1961) established in an experiment that cuttings separated from three year old gooseberry shrubs in four periods rooted from 4 to 45 per cent in the controls and from 17 to 78 per cent in cuttings treated with growth promoting substances, while in the case of 17 year old shrubs the percentages were 4 to 16 and 10 to 36 respectively. Thus the difference in favour of young parent plants was considerable. Equally conclusive results with other tree and soft fruits were reported by I. Y. Kocherzhenko (1936), S.G. Zaldastanishvili (1940) on olive, N. Shtefan (1952) and others.

It is well known that the process of regeneration is to a great extent connected with that of growth. It has been found, for instance, that the best rooting of sour cherry and plum soft wood cuttings coincides with the period of vigorous extension growth of shoots, this period varying in duration according to the variety and meteorological factors (M. T. Tarasenko and N. Shtefan, 1960).

Some investigators (N. P. Krenke, 1940; A. K. Yefeikin, 1957; M. A. Danilov, 1948; N. I. Dubrovitskaya, 1953, 1957 and M. T. Tarasenko, 1959) believe that due to the appearance of new shoots and a young root system, i.e., ontogenetically young cells and tissues, the rooting of cuttings leads to a certain rejuvenation.

P. M. Zhukovsky (1950) considers that when new meristems give rise to adventitious buds, the latter are similar phasewise to a seed embryo. He maintains that a tree is a mosaic organism in that it has branches different not only in their growth periods but in the phases as well.

It is obvious that the terminal buds which arise in the apical meristems and are older from the point of view of phase will be different from adventitious buds—phasically young—arising in the lateral meristems (phellogen, interfascicular cambium, callus, etc.).

V. N. Yurtsev established (1953) that trunk injury in *Malus Toringo* apples leads to the appearance of phasically young adventitious shoots from the callus formations. Just as in seedlings of the same species they have juvenile trilobate leaves while leaves of the mature trees are entire. On the other hand, whenever dormant buds become active on *M. Toringo* trunk the shoots bear mature leaves. This proves that adventitious buds are in a young phase.

M. T. Tarasenko (1959) found that shoots arising from adventitious buds on the parts of trunk nearest to the roots and on the roots themselves of old apple varieties begin to evidence characters usually common to apple trees in the juvenile stage of development, e.g., an almost complete absence of pubescence on shoots, buds, leaves and a weak bud development. He thinks that the similarity in the development of adventitious buds on roots and the root initials on shoots may not be accidental.

A number of apple varieties, e.g., Gravenstein and Suislepper, have been observed to produce suckers from the adventitious roots of the scion when planted too deep, i.e., with the point of union below the ground. This feature makes it possible to restore the old tissues of a scion back to their juvenile phase of growth, thus obviating the vegetative propagation, by cuttings and layers, of the varieties concerned (F. Passeker, 1961).

According to the studies of G. A. Kursakov (1959) in Michurinsk, apple roots do not pass through the phases of development characteristic of the aerial portion of the tree and that is the reason why all the shoots arising from an apple stock display the same morphological features regardless of what part of the root system the cutting was taken from.

N. Shtefan (1952) reported for plums and V. P. Polikarpov (1956) for sour cherries that the cuttings taken from sucker growth rooted and grew better than those taken from the bearing zone.

R. Kh. Turetskaya (1961) arrives at the conclusion that the capacity of cuttings to form roots depends on the vigour and duration of the growth of the parent branches, on the degree of their morphological and physiological polarity as well as on the action of growth promoting substances.

N. I. Dubrovitskaya (1961) considers the capacity of cuttings for rooting to be dependent on their growth period and the cultural practices used.

Of great importance is the establishment of the optimum season for taking cuttings, which has not been done so far for many species and varieties. In this the investigators have proceeded from the level of wood ripeness, the behaviour of lenticels in certain varieties, the phase and state of growth, the colour of shoots and the heteronomy

of the tissues and buds that gave rise to them. Also important are the actual time when a cutting is taken, the content of nutrients in it, the level of the metabolic processes in the parent plant and of the growth vigour in the parent shoot. The conditions under which the cutting is struck, including the action of growth regulators must also be considered.

Growth regulators are highly active substances similar in structure to the molecule of the indolyl-3-acetic acid (IAA) which are capable of stimulating the growth of roots and shoots. In the case of cuttings they encourage root initiation. Many investigators call these substances hormones or auxins.

Root Formation from Stem Tissue

All the branches of certain species with a tendency to vegetative propagation carry root initials in the form of peculiar swollen growths, or *burr knots*, at the base of shoots and leaves (H. A. Lek, 1924, Ch. F. Swingle, 1927). Such root initials can be observed on the numerous varieties of Paradise apple and quince, and on black currant. These species are easily propagated by stem cuttings.

Certain species and varieties with a tendency to vegetative propagation possess root initials in their shoots in the form of special groups of meristematic cells. The latter are situated at intersections of cambium layers and medullary rays, and form swellings enriched by parenchymatous tissue and nutrient substances. Under favourable conditions stem cuttings develop root systems from root initials.

Root formation in cuttings and layers is connected with the peculiarities of the anatomical structure of their lenticels. If they are not filled by dense layers of guard cells lenticels effect gaseous exchange and transpiration in plants and contribute to root formation. The root initial, lanticel and the swelling where the cambium is intersected by a medullary ray form an integral system responsible for root formation.

Root initials increase towards the base of a shoot where they are located in abundance. They are notably better developed on the side of the bud and in the upper portion of the internode.

Lateral roots arise endogenically, from the cells of the pericambium of the central cylinder of, mainly, the growing root opposite the radial rays of vascular bundles, and thrusting the cells of the cortex apart, they appear on the surface (Ch. F. Swingle, 1927).

Bush fruits that have lost their main stem and also fruit trees, which renew by sucker growth, such as certain varieties of sour cherry, plum and apple, develop roots of stem origin alone, known as adventitious roots. They arise endogenically too, but from the endodermis of from the pericycle of the stem possibly with the help of newly formed meristems. Adventitious root formation in soft and tree fruits depends not only on the inherited characters but also on the environmental conditions. The ability of certain plants to form adventitious roots is of considerable biological importance, particularly where there is a need for vegetative propagation.

I. A. Sheremet (1954) demonstrated that the adventitious root initials on black currant yearling wood arise from that part of the cambium which is opposite the medullary rays and lenticels.

The ability of certain species of tree and soft fruits to form suckers on their roots is a biological character which has arisen in the process of their development. For instance suckers in the sour cherry arise from the adventitious buds appearing on their roots. It has been found that very young (two to three years old) and very old and dying-off trees form almost no adventitious buds on their roots. Adventitious buds usually appear in the spring and autumn, on the roots 2 to 12 mm in diameter distributed in the top 5 to 25 cm of soil. Adventitious roots on suckers appear as soon as their underground part is suberized (Ya. I. Potapenko, 1953).

Roots may be formed from the callus of stem cuttings, particularly when they are soft-wooded. Callus formation is explained in the section on wound healing, Chapter 4. In the striking of cuttings first callus tissue is formed, then root initials develop which give rise to new roots.

Growth and root formation in plants depend on specific substances—auxins—produced in them. The movement of auxins can occur only in the direction from apex backwards along an axis, that is to say, it is polarized. The level of concentration and the speed of movement of an auxin vary

according to the physiological condition of the plant and the external factors.

Formation of roots on cuttings can also be encouraged by artificially produced growth promoting substances, such as napthalene acetic acid (NAA). These substances greatly stimulate the movement of nutrients towards the points of their application, thus speeding up root formation. At present chemical growth substances are extensively used to encourage root growth on cuttings and transplanted soft and tree fruits.

Methods of Vegetative Propagation

Tree and soft fruits are propagated by two methods, the *natural*, e.g., the strawberry (by runners), the dewberry (by tips of pendent canes), and the sour cherry, plum and raspberry (by suckers), and the *artificial*.

The artificial methods are very numerous, particularly those of grafting, which number over one hundred types. All these methods may be divided into two main groups: (1) *rooting of parts of stem* and (2) *grafting* or *budding*.

Rooting of parts of stem can be effected in two ways:

1. By the natural or artificial encouragement of root formation on stems of a parent plant with subsequent separation of newly developed plants. This is done by (a) special growths—runners (strawberry); by root or stem suckers (sour cherry, plum and raspberry); (b) by division of shrubs (gooseberry, sour cherry, filbert); and (c) by layers (gooseberry, currants, olive).

2. By the artificial encouragement of root formation on stems previously separated from the parent plant. This is done by (a) hardwood and semihardwood stem cuttings, e.g., currants, quince, Paradise apple; (b) softwood stem cuttings with leaves, e.g., gooseberry, sour cherry, plum; and (c) by root cuttings, e.g., raspberry and apple.

Grafting is achieved by (a) budding or transferring an eye or bud attached to a portion of the bark to a different plant, which is the principal method of fruit plant propagation (in the U.S.S.R.), and (b) by grafting or combining a shoot, the scion, of one plant with a rooted portion, the stock, of another which is achieved by various methods, e.g., whip and tongue-grafting, notch-grafting, chisel-grafting, inarching.

Compatibility and the Process of Union of Stock and Scion

The main condition for the successful union between stock and scion is their close botanical affinity, which is apparently due to the biochemical affinity of the protoplasm of their cells (P. Cerletti, 1960). The best union and growth are observed when apples, pears, plums and other tree fruits are worked on the seedling stock of related species.

Grafting is not infrequently successful with stock and scion belonging to different genera of the same family, e.g., peach and almond, peach and apricot, some varieties of pear and quince. In this case, however, abnormalities such as excessive callus growth and breakage are possible. Successful graftings of fruit plants belonging to different botanical families are rare and have had no commercial significance so far.

While budding is done by joining to stock a small bud-shield with one bud, grafting involves joining a small shoot with two to three buds to the stem or root of a seedling. Graft union occurs fairly quickly when the cambium of stock and scion are well fitted together. The first sign of the viability of the grafted or budded parts is the healing of wounds which is accompanied by the formation of what is known (after P. Sarauer, 1909) as agglutinating or intermediate tissue on their surface. This tissue is formed from the adjacent meristematic and other active cells.

In addition to the cambium which is the most active tissue responsible for cell-division, a vital role in intermediate tissue formation and in the joining is played by the parenchyma cells of the medullary rays and by the live elements of the phloem and xylem. New tissue fills the gaps between the scion and stock and forms simple vegetative tissue. In structure it is a typical parenchyma. Its cell walls are at first made up of cellulose which with time gets impregnated with lignin, is suberized and filled with starch. This tissue at first is uniform in structure and somewhat differs from the ordinary callus formed on wounds of the open type.

According to A. I. Kalashnikova (1953), the interspaces between stock and scion in budding are filled slower in sour cherries (20 to 25 days) and considerably quicker in

apples (5 to 7 days). The whole process of joining is longer in sour cherries (60 to 75 days).

There are cases when the healing of budding or grafting wounds only results in the suberization of the surface layers of cells on the stock and scion and there is in fact no joining, this phenomenon being termed the incompatibility of the stock and scion, or graft-incompatibility.

The normal joining and the subsequent common metabolic activity of the joined plant components is possible if the intermediate layer disappears completely or almost completely (as established by N. P. Krenke, 1950); if medullary rays, tracheids and vessels are differentiated in this vegetative tissue; and if a cambial link is established between the stock and scion and the new cambium starts forming xylem and phloem elements. All this ensures subsequent normal development for the budded or grafted plants.

Histological investigations conducted by J. Herrero (1956) showed that the incompatible unions may sometimes be due to the appearance of gaps filled with spongy parenchyma between the grafted components. This particular type of graft-incompatibility recognizable by the visual signs of malnutrition is not connected with poor joining.

It is accompanied by abnormal distribution of starch which is concentrated in branches while its content in roots drops until complete disappearance. An attendant phenomenon is phloem degeneration, notably in the stock. Graft-incompatibility may also be due to virus diseases.

There are cases of seeming compatibility when a grafted cutting develops normally throughout the first year and dies away in the spring of the following year, as it occurs when apple is worked on pear. This is a case of complete incompatibility. The cause of dying-off in this instance is the formation of suberized tissue by both the stock and scion over the autumn-winter period due to which the exchange of nutrients and water between them is stopped.

Stock Scion Interaction

When grafted or budded the two components, stock and scion, influence one another. In fruit growing the common practice in obtaining the planting material for new commercial orchards is budding or grafting by bud-shields or cuttings taken from mature trees.

According to I. V. Michurin, the propagation by budding, grafting or layering of immature, new hybrid varieties which have not yet acquired stability may lead—just as in sexual propagation—to the loss or change of their characters or the appearance of new heritable characteristics under the influence of the mature pollinator varieties and other external factors. This serves as the basis for the well-known *mentor method* developed by I. V. Michurin.

Noticeable changes due to stock influence are also observed in large-scale grafting of mature varieties, the changes or modifications being of a nonheritable character. For instance, cuttings taken from a tree which was worked on a dwarf stock a long time ago produce standard trees when grafted on standard stock, with no evidence of their stay on the dwarf stock. As a rule grafted fruit trees of all varieties enter the bearing period earlier than those raised from seed. Bearing begins considerably earlier when grafting is performed on semidwarf and, particularly so, on dwarf stocks as compared to standard stock. For instance, Sary Sinap, Candille Sinap and Rosemarine blanche apples begin bearing on the 4th to 6th year when grafted on Paradise apple and only in the 12th to 15th year on *M. silvestris* or *M. prunifolia* apples. Early bearing is also recorded for pear on quince, peach on blackthorn, etc.

The size of tree, its growth vigour and the shape of head in fruit trees varies greatly with the stock used. Apples and pears grafted on standard stock are invariably larger, more vigorous and have more upwards growing, often pyramidal, heads than those grafted on semidwarf and dwarf stock.

Fruit trees worked on standard stocks are longer-lived and retain productivity for a longer period than those grafted or budded on dwarf stocks. For instance, apples grafted on standard stocks live and bear fruit till they are 70 to 100 years old, while the same varieties grafted on semidwarf stock, all other conditions being equal, live and bear fruit till they are 25 to 40 years old.

Apple on Paradise apple and pear on quince register better colouring, bigger fruit with greater sugar content than the same varieties worked on standard stock.

The stock may influence the time of the phenological phases of flowering, the termination of growth and maturing of wood, winter- and drought-resistance and certain other

characters of the grafted varieties. The stock also influences the overall resistance of a fruit tree to the local natural conditions, particularly as regards the soil conditions. It is well known, for instance, that peaches and almonds grafted on plum and planted on extremely humid soil will grow and bear fruit considerably better than the same varieties grafted on almond which requires less humid soils. Conversely, peach on almond may be planted in drier soil than peach on peach or on plum.

Peach grafted on peach suffers more from freezing injury in the steppe areas of the Crimea than peach grafted on myrobolan plum or almond, the least affected combination being peach on apricot. This is due to the fact that peach on peach trees terminate their growing season 15 to 20 days later than the others and so are unable to harden before the frosts set in. The average cropping of peach grafted on apricot is 50 to 100 per cent higher than for peach on almond (L. A. Yershov, 1957). It will be seen that stock selection must be done on the basis of all its characters.

In its turn, the scion influences the stock. It has long been observed, for instance, that a vigorous scion tends to to increase the growth of the root system of the stock, particularly if it is of the dwarfing type, which can be observed on one to two year old seedlings in the nursery. According to data obtained by R. G. Hatton (1919) in Britain, the root system of certain types of clonal rootstocks of apples become more fibrous under the influence of certain scions.

In general it may be said that a wider selection of stocks can greatly extend the possibilities of cultivating fruit varieties in different natural conditions.

CHAPTER SEVEN

REQUIREMENTS OF FRUIT PLANTS FOR EXTERNAL CONDITIONS

The growth, longevity and cropping of tree and soft fruits largely depend on the timeliness and the extent to which their requirements for the adequate conditions of life are satisfied. This includes light, temperature, air, water, nutrient substances and the biotic (particularly the influence of soil burrowing organisms, rhizosphere and dead roots) and the topographical factors. All these factors act in entity rather than separately. One factor cannot be replaced by another, e.g., the lack of light cannot be met by an excess of warmth, but the intensity of one factor can make the requirement for another either greater or smaller; thus in colder areas trees require more light than in the warm ones.

Plants require for their life activity the simultaneous presence of all the external factors without exception. This confirms the law of equal importance of the various factors in plant life (V. R. Wiliams, 1936).

In the course of evolution every plant species, in its own habitat, has evolved its own inherited characters and requirements which horticulturists must know and satisfy in their cultural practices.

Fruit plant requirements for, and response and adaptation to, external factors vary according to the species, variety, rootstock, age period, periods of growth or rest, chlorophyll content, level of cropping, season, etc.

Interrelation and interaction of fruit plants and external factors are many-faceted. It is essential to learn how to master the external factors, i.e., to change and recreate the environment best suited for the corresponding requirements of the given plant, and to combat those processes

which harm the plant by inhibiting its growth and reducing its cropping (V. I. Vitkevich, 1964).

Below we shall examine the reaction of fruit plants to the main external factors.

Light

Light plays an exceptionally important role in the life of fruit plants. Light is indispensable for the synthesis of organic substances in leaves, acts as an activator and determines the speed of the growth and development of plant organs. To a certain extent light determines their shape. Consequently, it is an important ecological factor.

For normal growth, development and bearing, fruit plants require solar energy of a certain spectral composition and intensity. The more fertile the soil the more intensive the light must be.

The intensity of daylight is made up of direct light and scattered light reflected back from the sky. The degree of light intensity depends on the geographical location, height above sea level and the presence or absence of clouds. Not only the total amount of solar energy reaching the earth but also the duration of daylight or the daylength is of great importance. The response of plants to the period and duration of light is called *photoperiodism*.

The duration of the exposure to light greatly influences the growth and development of plants. When apricot and walnut, natives of the south, were placed in short-day conditions in the Leningrad Region they accumulated storage substances in their bark and wood and ripened and successfully passed through the winter (B. S. Moshkov, 1953).

Scattered light can be fairly intensive. According to L. A. Ivanov (1953), it plays an important role in photosynthesis, for it operates considerably longer than direct light. Moreover it penetrates into the top of a plant from all sides and is available to all leaves, influencing the size, site and longevity of shade leaves and providing an opportunity for the plant to make a fuller use of solar energy.

The capacity for photosynthesis is highest in apples, somewhat lower in pears and sour cherries and still lower in plums. As light intensity increases photosynthesis rate in apples and pears considerably increases until the end of August. Sour cherries and plums, on the other hand, do

not appreciably increase their photosynthesis after light intensity reaches a certain point. By the end of the growing season the photosynthetic mechanism ceases working, first in plums, then in pears and sour cherries and finally in apples (G. Friedrich and G. Schmidt, 1959).

Because of reduced interception of light by air the intensity of solar rays increases with increase in altitude. For example, A. M. Mamedov (1958) reported that the fruit of certain apple varieties, such as Jir Gaji and Sary Sinap, grown in mountainous regions at an altitude of 1029 m, had a better aroma, brighter colour and two to three times as much sugar as the same varieties grown in lowlands, at an elevation of 370 m.

The importance of scattered light for plants grows as we move northwards. The higher the orchard is sited the less scattered light the trees receive. The least amount of light reaches trees growing in hollows, valleys and at the foot of hills or mountains.

Insolation received per orchard depends on the aspect of its site. The highest insolation comes from the south and the lowest from the north. The eastern portions of a tree are better lighted than the western ones.

Clouds are a great limiting factor, particularly rain clouds, which screen out light to a high degree.

The outer parts of a tree get maximum light, 5 to 14 times more than the inner parts. That is why more branches and fruiting growths die in the inner part of a tree.

Foresters assess the capacity of a species to endure shade, or its shade tolerance, by the density of its leaf cover. The denser the leaf cover and the slower the natural process of reduced leaf and shoot production, the less light a tree needs to meet its requirements. This has served as a basis for the elaboration of a scale of relative shade tolerance ratings of forest trees, representing various degrees of ability to endure shade.

Most fruit plants are light-lovers. With inadequate light their growth and bearing are impaired. A special shade tolerance scale for fruit plants has been compiled by A. V. Petrov (1956). It is based on a correlative relationship between the average leaf surface and the length of the leaf stalk and internode. Apple trees are able to reduce the amount of leaf surface in the shade by increasing the length of the leaf stalk and/or internode. According to their shade

tolerance, apple varieties may be placed in the following order (starting with the least tolerant): Snezhny Calleville, Wealthy, Borovinka, Aport, Pippin Litovsky, Korichnoye Polosatoye, Papirovka, Antonovka Obyknovennaya, Streifling.

It should be remembered that, as the forester H. Mayer pointed out, trees have greater tolerances in the southern parts of their distribution range and lower in the northern parts.

With age, trees and shrubs become less shade tolerant and require more space in orchards. On better sites, according to E. Ramann (1893), all species can be grown closer together. H. Hesselmann (1904) found that hazelnut has a scant top on poor soil and a denser one on richer soil. According to H. Lundegardh (1930), this lesser requirement for light may be due to better tree care encouraging the tree to produce more chlorophyll, i.e., an ampler nitrogen supply giving the leaves a dark-green colour. In general, better feeding and watering can to a certain degree compensate plants for lack of light.

Light can fall on a tree from above, parallel to its central leader; or from the sun-exposed side, in which case the tree gets most light if it is open to the south. It can also be reflected from neighbouring trees, buildings and other objects, and from the earth and grass, encouraging the growth of bottom leaves.

Insolation per orchard tree depends to a great extent on the size of the trees and the distance between them; the smaller the distance and the bigger the trees the less light each receives. For this reason densely planted orchard trees tend to push their branches upwards; the leaves assume shade leaf structure, and become smaller and die, particularly the bottom ones located in the heaviest shade. As a result, shoot-bearing branches cease growing and dry up; the fruiting growths, spurs, etc., gradually move to the outer fringe of the tree and the yields drop sharply.

High-intensity light favours high quality in fruit, e.g., apples, pears and peaches grown in full sun develop colour well.

Pruning and a certain amount of displacement of branches through propping heavily yielding trees are aimed at placing leaves in better light conditions, thus favourably influencing harvest quality and quantity; raspberry,

for instance, gives a 25 per cent higher yield when tied to wire instead of to stakes which reduce lighting.

Interplanted orchard crops, such as soft fruits and vegetables, have 20 to 65 per cent reduced yield depending on the planting density of the principal variety. This is largely due to insufficient lighting in the shade of the trees.

Fruit trees growing closest to shelter belts are usually poor croppers; due to insufficient lighting they tend to grow orchardwards and so become lop-sided. There should be sufficient space between a shelter belt and the first row of orchard trees to avoid this.

The fruit grower should know and satisfy the light requirements of the variety he deals with, with a view to increase photosynthesis. This may be achieved through better plant feeding, provision of proper spacing between trees, using the technique of head formation by pruning, and timely removal of interplants from between the rows.

Temperature

Similar to light, air and soil temperature is a principal environmental factor, influencing the processes of growth and development of plants and their yield. The problem of soil temperature and the development of plants has strongly attracted the attention of research workers of different countries in recent times (J. K. Shaw, 1959). Fluctuations in temperature influence chemical transformations and circulation of all substances in plants, transpiration in leaves, rate of passing through the phenological phases, microbiological processes in the soil, etc. Fruit plants make better growth in the range of optimum temperatures and tend to be longer-lived and heavier-yielding.

When metabolic activity in plants is at its highest, respiration is very intensive. With the advent of summer heat respiration does not increase in step with the increase in air temperature. At the end of the growing season respiration intensity increases until the shedding of leaves. From early spring till summer, increases in air temperature heighten respiration. At the hight of summer, leaves are almost unresponsive to increases in temperature. Shortly before the shedding of leaves, the trees no longer react in a predictable manner to changes in temperature (G. Friedrich and G. Schmidt, 1959).

As reported by I. A. Muromtsev (1963), the direct action of temperature is characterized by the extraordinarily short period between the reception of the temperature-change signal by the cells of the growing zone of a root and the reaction to it. This reaction is manifested by a change in the growth rate. Root growth never proceeds evenly but in typical waves of growth stimulation and inhibition. Any drop in temperature causes a sharp decrease or temporary stoppage in growth, after which growth is resumed at a new level corresponding to the new temperature of the soil.

Because of the adaptation of fruit plant species to certain thermal conditions they require a particular range of temperatures, outside of which growth and development is impaired or even stopped until the death of parts or the whole of a plant. For normal growth and development plants require not only a frost-free period of a certain duration but also a corresponding rhythm of temperatures throughout the growing season. This is graphically illustrated by hothouse peach culture where the best growth and cropping is achieved by lowering the day and night temperature by 4-7°C during flowering and by 2-3°C during stone formation, compared to the previous phases of development. In the open, too, fruit plants require different temperature conditions during different phases of their vegetation. For instance, in the middle belt of the U.S.S.R. apple fruit bud growth begins at a daily temperature of 8 to 10°C and root growth at 0 to 2°C.

According to investigations conducted by I. P. Overcash and N. H. Loomis (1959) bud bursts in the pear variety *Pirus communis* L. in the southern part of the state of Mississipi and along the coast of the Mexican gulf are late and straggling after warm winters; flowers drop heavily and there can simultaneously be seen buds unopened and burst and those which have produced shoots and fruit.

From a study of peach and apricot in the Crimea, S. I. Yelmanov (1959) concluded that "winter rest" is an indispensable thermal phase in the development of fruit buds in natural conditions during which reduced temperature and respiration guide metabolism towards the synthesis of starch and its accumulation in the tissues at the base of buds—which is discontinued as soon as its maximum is reached. Morphologically this corresponds to the

phase of the formation of the pollen mother cells and their passing over to reduction division. Bud death at temperatures of 18 to 20°C in November-December was due to a lack of starch.

The more to the north or the higher in the mountains trees of the same variety grow the later their fruits ripen. For instance, the difference between the ripening of apples, such as Papirovka and Astrakhanskoye Beloye, in the south and the north of the Dniester Region, can be 8 days or more, while varieties such as Snezhny Calleville and Landsberg Reinette are late-autumn varieties in the southern districts of Moldavia and winter ones in the northern (G. A. Kabluchko, 1955).

Fruit ripening in the mountains of the North Caucasus and the Trans-Ili Alatau is delayed by three to four days with each increase of 100 m in altitude (A. P. Dragavtsev, 1952) and in Western Europe by 8 days. There is less retardation in fruit ripening in the east, due to a greater tension of warmth during the growing season there. The period of fruit ripening is also influenced by the aspect, soil colour, species, variety and other factors.

Fruit tree growth is mainly influenced by temperature conditions throughout the spring, particularly during the morning hours, and photosynthetic assimilation, by mid-summer and autumn weather. Moderate day temperatures favour photosynthesis, while high temperatures, whether by day or night, hinder it. Fruit ripens better at increased temperatures at the end of summer and in autumn. Wood matures better in the conditions when temperatures in late autumn and early winter decrease without passing beyond the ecological zero point (H. Lundegardh, 1930).

Temperature is one of the main environmental factors that determine the distribution of fruit plants according to the climatic zones of the U.S.S.R. Local climate, or microclimate, may influence the distribution of plants within a zone.

According to their requirements for higher temperature fruit plants in the U.S.S.R. may be placed in the following order (highest first): the *northern zone*—mountain ash, bird cherry, Siberian apple, berries; the *middle zone*—apple, sour cherry, plum, pear; the *southern zone*—sweet cherry, quince, apricot, walnut, pecan, filbert, almond, peach; the *subtropical zone*—pistachio, sweet chestnut,

persimmon, fig, olive, feijoa, orange, mandarin, lemon, avocado.

The optimum summer temperature requirements for apple varieties vary greatly—11°C for Borovinka, 13.2°C for Wealthy, 16.6°C for Grahams and 19.3°C for Peyte. The influence of summer temperatures should be studied in all fruit-growing zones of the U.S.S.R. in order to establish the boundaries of commercial cultivation of apples, pears, plums and sour cherries.

To assess the influence of temperature on the growth and development of fruit species three *cardinal points* have been accepted: the *minimum* and *maximum* at which growth is still possible, and the *optimum* at which plants make the best growth.

Air and soil temperature at the level of minimum limit is the commonest cause of injury and death in fruit plants.

Winter injury of fruit plants causes a sharp drop in their productivity and longevity and, occasionally, their death. Within the present boundaries of the U.S.S.R. considerable damage to orchards from winter injury has been recorded 20 times (since 1841). The number of injurious winters in the U.S.S.R. varies from zone to zone. In Uzbekistan, for instance, stone fruits were injured 21 times and pomes 8 times in the 44 years from 1904 to 1948. In the foothills of the Crimean mountains in the 12 years from 1940 to 1952, apricots gave good crops four times, poor crops three times and no crop at all six times, the two latter instances being due to damage to fruit buds or blossoms by winter or spring frosts.

In certain years winter injuries assume catastrophic proportions. For instance, in the winters of 1939-1940 and 1941-1942 about 200,000 hectares of orchards were destroyed in the Russian Federation alone. In the same two winters Germany lost some 53 million orchard trees.

Back in 1875-1876 about 80 per cent of all productive orchards were destroyed by frost in the nonchernozem zone. The winter of 1928-1929 saw the destruction of 20 per cent of apple trees and 60 per cent of pears in Czechoslovakia, and 50 per cent and 80 to 90 per cent of pears in southern and central Poland respectively.

In the winters of 1938-1939, many fruit trees were killed all over the European part of the U.S.S.R. This was

mainly due to the freezing of the root systems. In the exceptionally severe winter of 1953-1954, 25.3 per cent of all the trees in the Sad Gigant State Farm and 10.2 per cent in the Agronom State Farm were damaged. The worst hit were London Pippin, Reinette de Champagne and Wagner Reinette varieties. A substantial part of the fruit trees of the Uzbek Republic were killed by frosts in the winter of 1954-1955.

Winter-Resistance in Plants

Winter-resistance and especially resistance to freezing injury has long been an object of study. Buffon and Duhamel du Monceau in 1737 and J. Senebié in 1800 believed that the death of plants from severe cold came as a result of ice forming in the tissues and destroying them. J. Sachs (1860) maintained that plants died not when they froze but when they thawed. However M. Müller-Thurgau (1880, 1886) who repeated J. Sachs' experiments arrived at a different conclusion, viz., that plants start dying in the process of freezing during which ice is formed from the water taken from the cells.

Later H. Mollish (1897) demonstrated that freezing is commonly attended by dehydration and changes in the structure of the protoplasm until, at a high level of dehydration, the structure collapses.

H. Gorke's studies (1907) led him to the conclusion that low temperatures bring about chemical changes in the dissolved protein of the protoplasm; he also considered that the death of cells is due to ice formation and the resultant dehydration, followed by the irreversible coagulation of proteins and, often, colloids.

A new stage in the study of the physiology of winter-resistance in plants was begun by N. A. Maximov (1913) and his associates. As a result of their investigations conducted over years a new light was thrown on many problems of the mechanism of cell injury and death at low temperatures and of the defensive reaction of the protoplasm.

Literature in this field was summarized in books by I. I. Tumanov (1940) and I. Levitt (1941, 1956). According to I. I. Tumanov (1940), woody plants usually die in the winter only after the appearance of ice in the protoplasm. If ice is formed in the intercellular spaces plants can sur-

vive very high levels of dehydration—up to the air-dry condition. Hence, frost-resistance of the woody plants is not necessarily connected with their water-retaining capacity. Similar results were registered in the work of I. Modlibowska and W. S. Rogers (1955) and A. Sakai (1955).

The process of the preparation of plants for winter, or their hardening up, includes a complex of physiological and biochemical changes which increase the resistance of cells towards adverse winter conditions. I.I. Tumanov distinguishes two phases in the hardening-up process. The first phase roughly begins with the cessation of extension growth and is characterized by an accumulation of nutrient substances and their partial hydrolysis. The second phase proceeds at subzero temperatures. It entails a gradual dehydration of cells on account of the increasing amounts of ice in the intercellular spaces and a complex reorganization of the protoplasm components.

As shown by the experiments of I.I. Tumanov and O. A. Krasavtsev (1955, 1959) and A. Sakai (1960), hardening-up occurs at any subzero temperature which does not bring about tissue injury. With a slow drop in temperature from —5°C to —60°C, the shoots of a number of species, e.g., black currant, could survive the temperature of liquid nitrogen (—195°C). Consequently, the potential frost-resistance of plants is virtually unlimited.

However, fruit plants possess an ability for hardening-up only during the period of no active growth, which in Moscow is from October to April. In summer, plants cannot be hardened even under the conditions of a slow drop in temperature (Fig. 62).

During the hardening-up process plant metabolism undergoes drastic changes. As a result of starch hydrolysis, sugars and fats are formed. The latter then participate in producing lipoid layers on the surface of the protoplasm thus increasing its elasticity. According to Ye. Z. Oknina (1962), tannin-lipoid and protein-lipoid compounds appear in cells and the contraction of protoplasm begins which is manifested in the disappearance of the plasmodesmata and the withdrawal of the protoplasm from the cell-walls. P. A. Genkel and Ye. Z. Oknina (1952, 1954) consider that the latter condition can serve as an indication of the degree of winter rest and tissue frost-resistance in plants.

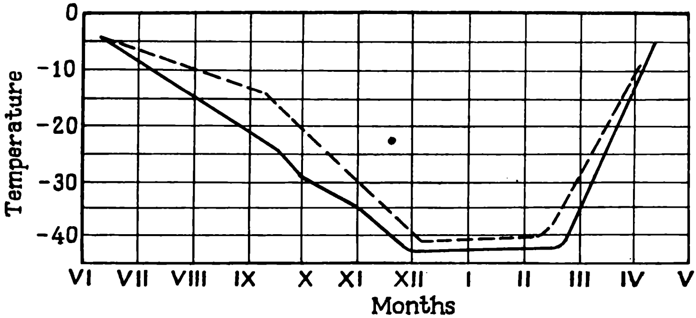


Fig. 62. Changes in frost-resistance of apple-tree shoots throughout the year

Bottom continuous; *line* stands for temperature at which shoots of Borovinka variety die when artificially frozen; *top dotted line* is the same Jonathan variety (after Childers).

A number of studies have shown that the hardening-up process leads to an increase in protein nitrogen (K. M. Poplavsky, 1952, 1958; D. F. Protsenko, 1958), particularly in its water-soluble fraction. Water-soluble proteins are ascribed an exceedingly important role in frost-resistance of plants (D. Simonovich and D. K. Brigs, 1949; K. Oland, 1959; D. F. Protsenko, 1958).

In L. I. Sergeyev's view (1961), frost-resistance of cells is greatly influenced by oligosugars (primarily by raffinose and sucrose). On the other hand, I. M. Vasilyev (1956) believes that they are reserve substances used in the production of monosaccharides.

During the hardening-up process changes also occur in the colloidal-chemical properties of the protoplasm and in the free and bonded water ratio; respiration intensity is drastically reduced; etc. (Salakadze, 1949; Stark, 1936; W. A. Long, 1930; Y. Z. Oknina, 1962).

Certain workers (M. Kh. Chailakhyan, 1935; B. A. Keller, 1935, and others) paid a lot of attention to the study of the viscosity of the protoplasm as a factor influencing the resistance of plants to low temperatures; and also to the chlorophyll level (D. F. Protsenko and L. K. Polishchuk, 1948; T. Godnev and M. Terentyeva, 1952; and others).

They consider that fruit plants with a higher frost-resistance have a higher chlorophyll content in their xylem and phloem tissues than those less frost-resistant.

All these processes are essentially of the adaptive nature and the way they vary with species and varieties reflects the latter's degree of adaptation to the environmental conditions.

This adaptation is based, according to I. V. Michurin, on the agreement or otherwise of the genetically fixed rhythm of the seasonal development of plants and the dynamics of the natural conditions. And this is the reason why there are no varieties, nor could be, that are universal in frost-resistance, i.e., equally frost-resistant in whatever zone they are grown. The Siberian apple, for instance, which can survive —55 °C in its native parts is damaged in areas further to the south in winters with unstable temperatures (F. Gollmik, 1941, Ya. S. Nesterov, 1948). Similar cases have been reported for the Ussurian plum and the Siberian apricot. Antonovka Obyknovennaya is quite hardy in the middle belt of the U.S.S.R. while it may be damaged by frost in the Kuban area and the Ukraine because of the unfavourable conditions for wood ripening.

The above examples, as well as the considerable variation in the type of injuries suffered by trees in winter time, makes it advisable to distinguish between the two definitions of *winter-resistance* and *frost-resistance*. The former should mean the ability of a plant to resist the entire complex of adverse winter conditions while the latter stands for resistance to low temperatures alone. In other words, winter-resistance is a much wider term.

The levels of resistance depend not only on the conditions of hardening-up but they are also greatly influenced by the conditions in which trees developed in the previous growing season. Normal ripening of wood and the resultant hardening-up in trees may be hampered by a lack of warmth during the summer. According to P. G. Schitt this was the precise reason why the pear failed to be winter-resistant in the nonchernozem zone of the U.S.S.R.

However, reduced winter-hardiness is much more often caused by irregularities in the moisture regime. An analysis of the outwintering of fruit plants in the Moscow Region over 100 years (G. Gogoleva and D. N. Durmanov, 1962) showed that orchards suffered considerable damage only in those years when there was a serious disruption in the moisture regime during the growing season. Reduced winter-

resistance in the conditions of unstable watering in a pot culture house was reported by M. A. Solovyova (1957).

Light favourably influences winter-resistance in plants by increasing their photosynthetic activity. In many cases damage to orchards is brought about by over-cropping which has resulted in the undernourishment and weakening of trees. In the winter of 1939-1940 it was very often the local, resistant varieties that were killed after excessive cropping, while the imported, southern varieties which had not bloomed that year survived.

It can be seen that the causes and types of tissue death are complex and varied. Relying on the capacity of plants for self-defence the fruit grower can help them in no small measure to mature and harden up properly and in good time, by planting shelters, performing timely tree care, and by other measures.

Influence of Temperature on the Aerial Portion of Plants

Damage to trunk, branches and buds. Whereas in the periods of active growth of the aerial portion of the tree the cambium is most sensitive to low temperatures, it becomes the most winter-resistant tissue during the rest period as compared to bark, young wood and particularly to the pith.

Being the most vitally active tissue the cambium hardens up better than any other tissue in the autumn. Sometimes frosts badly damage young wood in apple, pear and cherry trees. This usually leads to a certain slowing down of vegetation and a weakening of growth in the following year. The cambium will produce new xylem and phloem and the damaged trees will resume normal development, yet their frost-bitten branches will be more liable to breakage than the unaffected ones.

However, cambium tissues may also be damaged or destroyed. This is more often the case in the autumn with the sudden advent of frosts, in winter, with sharp temperature changes and in spring at the time trees pass from the rest period to growth. In such cases the cambium is devoid of its hardiness as it resumes its vital activity and can be damaged or even destroyed by relatively weak recurring frosts.

Freezing injury leads to a change in the colour of xylem and pithto orange in cherry and plum, red in apricot, brownish in apple and dark-brown in pear.

Sharp changes in the temperature of the air in the winter time are very damaging to tree fruits. For instance, the hard frosts which set in Poland after the unprecedentedly mild January of 1956 killed up to 80 per cent of all apricot trees and up to 20 per cent of peach trees (Z. Yarochowski, 1957). Frosts alternating with thaws are particularly dangerous for tree fruits because trees lose some of their hardiness and are liable to be damaged or destroyed at a sudden drop in temperature.

Sometimes early frosts in winter bring about *tissue necrosis at the collar and on the inner sides of the crotch.* The reason for this is a slower hardening-up of tissues in those places. They are regenerated by the callus of the adjacent live cambial cells. Restoration of damaged tissues is more successful if the dead matter is removed during the second spring rather than the first.

In February and March the sharp fluctuations of heating and cooling of the tree bark result in so-called *sun burns.*

The resultant sudden change from the thawed to the frozen state brings about the death of tissues. Sun burns in apples are notably severe and frequent in the Primorye Territory. They are due there to the exceptionally great daily changes in temperature in February and March brought about by solar irradiation (V. A. Tyrina, 1957).

A. Mix (1916) reported that in February the temperature under the bark of apple trees dropped by 17.5° (from + 14.60°C to —2.75°C) between 2 p.m. and 9 p.m. on the south-western side and only by 3.3°C (from —3.85°C to —7.15°C) on the north-eastern side. The experiments of A. Mix (1916), V. K. Mityurev (1951) and I. N. Kotovich (1960) showed that the temperature of the bark on a sunny day may exceed the temperature of air by 20 to 40°, while the daily temperature amplitude of the bark and cambium may reach 25 to 40°. It is such sharp fluctuations of temperature which cause the sun burn of the bark.

K. P. Lange (1949) reported that in the middle part of the Volga area in 1941 the difference in temperature between the sides of fruit trees in the sun and in the shade was 5°C in the morning and up to 7-8°C in the early afternoon. Even greater differences for apples were registered

in Omsk (A. D. Kizyurin, 1950) and the Soviet Far East (I. M. Vasilyev, 1951, V. A. Tyrina, 1952).

During the winters of 1931-1932, 1933-1934 and 1934-1935 in the Kuban area temperature changes reached 27° over a 10 day period in November, 29° in December and 27° in February. This was accompanied by noticeable tree damage.

The sun burns appear on the southern side of trunk and branches as a result of warming up of their surface and change of their tissues from dormancy to the state of activity, which at the time of the subsequent lowering of temperature are damaged or killed.

Sun burns on tree trunks can be prevented or greatly reduced by forming low tree heads so that the limbs have ramifications and provide cover for the weak spots; also by tying fir branches and other material round the trunks and the bases of the main limbs, by whitewashing the trunks, etc.

Varieties with low spreading heads are more winter-resistant than pyramid-headed ones.

At a sudden and sharp drop in the air temperature mature fruit trees may develop *trunk splitting*, i.e., deep crevices going through the bark, the young wood and sometimes reaching the centre of the trunk. This is due to a great difference in temperature between the surface and the inner layers of tissue which leads to ice formation and dehydration with consequent high tensions and ruptures of tissues.

Resistance to freezing injury is inherited, which must be taken into account in the selection of varieties for the given natural and cultural conditions. Trees with freezing injury were found on examination to be deficient in calcium, which is very prominent in the formation of the inner layers responsible for the bonding together of the various elements of xylem (R. Rol, 1955).

Tree and soft fruits are much more often damaged than killed by winter frosts, and in spring growth is resumed and wounds are healed. It should be noted here that root systems have a greater capacity for regeneration than the aerial portion. Regeneration takes place when bark tissues and the cambium, or even parts of them are left intact. Any serious damage of these tissues in branches or roots results in the dying-back of the damaged parts (M. A. Solovyova, 1957).

Winter varieties of apples which have a longer growing season are less frost-resistant than the autumn and particularly the summer varieties.

Sometimes the main limbs of a tree or even the entire tree die from relatively mild frosts if there are winds. The explanation lies in the heavy loss of moisture by such trees resulting in the desiccation of tissues.

Nursery plants, because of unripe shoots, and old trees, because of a lack of storage substances, are less resistant than young or well-established bearing trees. The age of a tree by itself is not always the decisive factor because the ripening of tissues is influenced by the amount of nutrients stored in the tissues and the time of the cessation of shoot growth.

Shoots are killed if they are not yet ripened, especially their tips which contain more water than the middle portion and base of shoots (Fig. 63).

The studies of winter-resistance in plums in Uzbekistan convincingly revealed that the decisive factor was the winter-resistance of fruit buds which largely depended on the rate of their development throughout the winter. Generally speaking, however, plums in the north of the republic had a definite advantage in terms of the winter-resistance of fruit buds and the regularity of bearing over apricot, peach and even sweet cherry (D. I. Tupitsin, 1955). Relatively lighter winter damage to the fruit buds of the late blooming peach varieties was reported, as compared to those which are more easily induced to growth by a thaw (I. Stoichkov, 1958).

The less the fruit buds are developed and the more deep and prolonged their dormancy, the more frost-resistant they are (I. M. Ryadnova, 1941; L.I. Sergeyev, 1950; V. M. Turkov, 1959). Plants grown from buds taken from the middle and top portions of cuttings and from upper parts of the head are more resistant than those grown from buds taken lower. Consequently, winter-resistance in plants, apart from being a varietal characteristic and varying with rootstock, cultural practice, climatic and other conditions, is also influenced by the position of the bud on the cutting, by the type of cutting and by the position of the cutting in the head of the parent tree (T. K. Poplavskaya, 1958).

A. M. Sholokhov's studies (1961) showed that apricot fruit buds reach their maximum frost-resistance in the

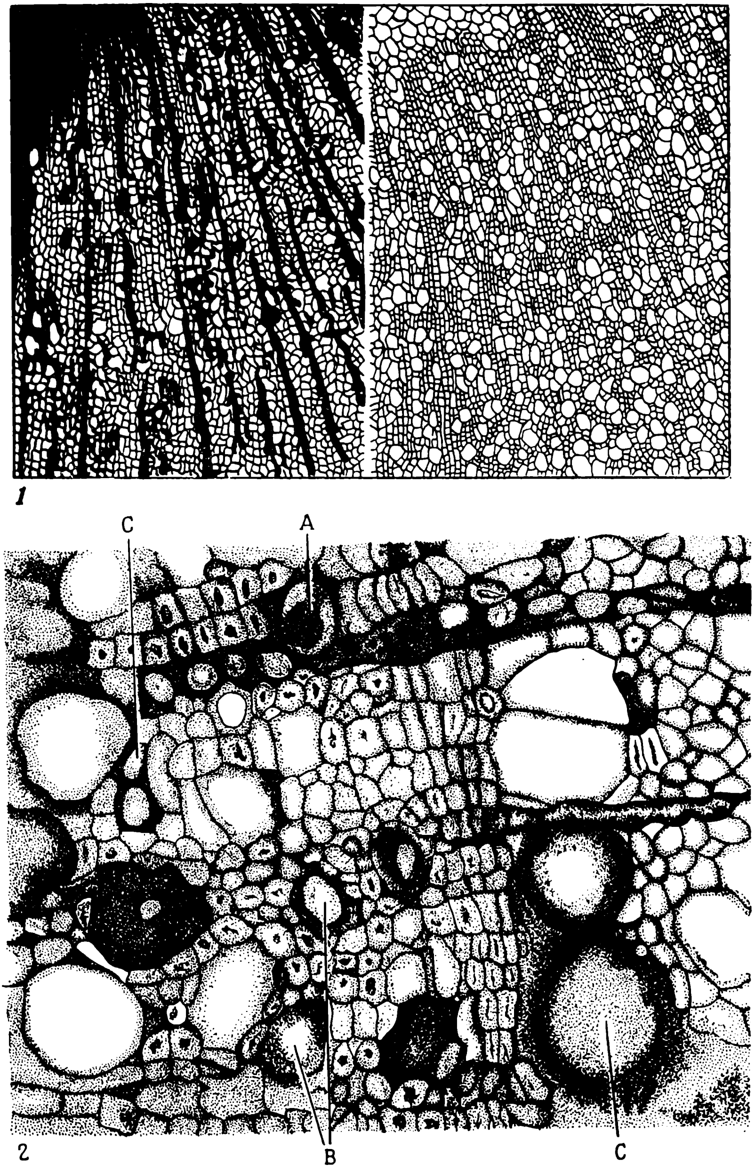


Fig. 63. Anatomical structure of frost-damaged sap wood (cross sections of shoots)

1—apple; uninjured and frost-killed and turned brown (after Warring and Hilborn); *2*—sour cherry; *A*—vessels clogged with gum; *B*, *C*—softening and gumming of walls of lignin elements (after Woichitski)

period of archesporium tissue development. The longer this period the more winter-resistant the apricot varieties are. Fruit buds of different apricot varieties in the same stage of development display varying degrees of frost-resistance. When breeding for winter-resistance selection should be made for varieties with a slowed tempo of fruit bud formation and the longest period of archesporium tissue development.

Fruit buds are normally killed before wood buds are, but sometimes the order is reversed, for everything depends on the degree of their preparedness for winter. Usually fruit buds become active in late winter, with the advent of relatively warm days, and ahead of wood buds, due to which they are more liable to be nipped by frosts. This is more often the case with stone fruits, particularly peach, apricot and almond, when unexpected warm days at the end of winter activate them, cause them swell or even burst, while a subsequent drop in temperature may damage or kill them.

Winter injuries to outwardly quite healthy branches of apple, pear, sour cherry and certain other fruits, may later result in severe ovary drop.

Influence of temperature on blossoms and fruits. There is hardly a spring without a sharp drop in air temperature. According to P. G. Schitt's observations, northern forms of plants start spring growth when transferred to southern conditions somewhat earlier than the local, more warmth-loving forms. That is why the blossoms of northern plants are more liable to suffer from early-spring frosts. On the other hand, the southern forms of fruit plants which are transferred to northern conditions are damaged by early-autumn frosts because they start growing later than the northern forms and cannot discontinue growth and ripen in time.

D. F. Protsenko reports a certain variation in the critical temperatures for buds, blossoms and fruitlets in different fruit species and varieties. Not only do the actual temperatures matter, but also the duration of exposure. Swelling apple buds are killed by a six-hour exposure to —8 °C; at pink-bud stage, destruction follows after four hours at zero temperature and after two hours at —8 °C; from 85 to 92 per cent of flowers are killed after four hours at —4 °C; ovaries are killed after four hours at —3 °C.

Data on the critical temperatures at blossom time for various fruit plants are given in Table 10.

Table 10

Critical Temperatures at Blossom Time of Various Fruit Plants (in degrees Celsius)

Species	Beginning of pink-bud stage	Flowering	Beginning of ovule formation
Apple	—2.75 to —3.85	—1.65 to —2.2	—1.1 to —2.2
Almond	—3.3	—2.75	—1.1
Peach	—1.65 to —6.6	—1.1 to —3.85	—1.1 to —2.75
Sweet cherry	—1.65 to —5.5	—1.1 to —2.2	—1.1 to —2.2
Sour cherry	—5.5	—2.75	—
Pear	—1.65 to —3.85	—1.65 to —2.2	—1.1 to —1.65
Plum	—1.1 to —5.5	—0.55 to —2.2	—0.55 to —2.2

A sharp drop in temperature may kill all flower parts, whether exposed or still within the bud. Sometimes only pistils or stigmas are destroyed in certain varieties of apples and pears.

In one case in the Crimea in 1948 a drop in temperature down to —6°C did not result in the killing of the apple ovaries just formed. This was due to timely smoking and, what is more important, to the cloudy conditions on that day.

Fruit of winter varieties may occasionally be destroyed by the first autumn frosts if not harvested in good time.

Best-quality fruit are only harvested when there have been optimum air temperatures throughout the summer. Sharp increases in temperature produce burns on, or retard the ripening of, many fruits. This has been observed in certain varieties of plum and pear in the Crimea, California and other areas.

Over-cropping, particularly in conjunction with poor tree care, may also contribute to freezing injury, as was the case in the Ukraine in 1923-1924 and in the Krasnodar Territory in 1933. The influence of excessive cropping may sometimes be more important than the varietal differences. Thus, for instance, such tender apple varieties as Yellow Bellefleur and Simirenko's Reinette which had produced no crop the previous year survived the severe

winter of 1926-1927 in Voronezh while Antonovka Obyknovennaya—after an abundant cropping—was damaged by frosts.

Fruit plants suffer more from low winter temperatures when they are planted in unsuitable soils (with a high water table) or in hollows, or in orchards with little shoot growth, unprotected by windbreaks. Fruit grower must take appropriate and timely care to increase winter-resistance of fruits.

Influence of Temperature on the Root System of Plants

The root system has evolved in the sheltered conditions of the soil. Because of this it has developed a lesser resistance to low temperatures than the aerial portion of the plant. Yet its life activity, just as that of the entire plant, depends in no small measure on the temperature. For instance, the temperature of the soil has a direct bearing on the permeability of cell protoplasm, on which the speed of mineral nutrient intake by roots depends. Rysselberghe (1901) found that the normal state of plasmolysis was reached in plants at 20°C seven times as rapidly as at 0°C.

The problem of the influence of temperature on root growth in tree and soft fruits has for years been prominent in research programmes.

J. Tanaka reported from Japan in 1935 that roots of various fruit plants started into growth in strict accordance with their warmth requirements: in early February at the soil temperature of 4-5°C for plums and peaches, in mid-February onwards at 7-8°C for pears and apples, in late March at 9-10°C for figs and grapes, in mid-April at 12°C for chestnut and persimmon, in mid-May at 16-18°C for the citrus fruits.

According to M. Yu. Gushchin (1939), fruit tree root growth irrespective of depth of roots, began in the southern Ukraine at a temperature of 5-6°C. In pot culture, roots of apples began to grow at 4-5°C, pears at 6-7°C, sour cherries at 6°C, apricots and peaches at 12-22°C.

G.T. Nightingale (1934) and W.S. Rogers (1939) reported that apple root growth was weak in winter, at temperatures from 1.7°C to 7.2°C, reaching its peak at temperatures between 7.2 and 20.5°C. In winter, only the deepest lying roots grew.

A. P. Tolsky (1905) reported that the horizontal roots of pine grew at a temperature of 6°C, while 0.1°C was sufficient for the vertical ones. Root growth at temperatures from 0 to 3°C was observed in cloudberries by V. P. Dadykin and in oak by O. B. Mikhailovskaya (1953). M. Yu. Gushchin (1941) established that root growth moved to deeper layers in summer. Vertical root growth in Slavaynka apple studied by the root observation method was 0.2, 0.3, 0.7 and 1.1 mm per day at temperatures of 0.4, 0.9, 3.8 and 6.0°C respectively (Ye. V. Kolesnikov, 1953).

On the strength of the above studies it can be concluded that absorbing root growth is more often brought to a standstill by low temperatures than the axial root growth. Consequently, axial roots can also grow at lower temperatures.

It has been found that the absorbing roots of the cloudberry spread in the permafrost can grow at the very low temperature of —0.1 or —0.2°C (V. P. Dadykin, 1952), while cacao tree roots stop functioning and begin to die when the temperature drops to +12°C (Ye. N. Mikhalyova and N. Shipchinsky, 1951).

Thus it can be seen that root growth in different fruit species occurs at widely varying soil temperatures. High temperature values are required, for instance, by the citrus fruits. This was very well illustrated for the lemon by I. I. Tumanov (1954) and R. L. Vinokur (1957) who reported a five-fold increase in root growth at 33°C compared to 10°C in 1951 and a 4.3-fold increase at 33°C compared to 15°C in 1952. Warming the soil and, consequently, the roots in the citrus fruit culture increases the influx of nutrient substances from leaves into roots, thus increasing photosynthesis in the plants. This, in R. L. Vinokur's opinion, may be one of the reasons for a more vigorous root and shoot growth.

A. D. Romashko (1953) observed that the root systems of Pippin Litovsky apples which were kept longer under low soil temperatures in spring retained a great number of ovules and fruits than the control trees (59.4 compared to 47.8 per cent).

The freezing of soil to the depth of 5-10 cm in the forest-steppe areas of the Ukraine in the autumn and early winter did not stop root growth in the deeper layers. If the soil is not frozen, root growth occurs in winter too. This is very

important because the fruit grower is able to lower or raise the soil temperature in spring—by mulching, watering and loosening.

High temperatures have a negative influence on the growth of roots in apples and certain other species. Thus, in the Crimea, apple root growth stopped at 30 °C. In Michurinsk apple root growth stopped at 28-30 °C in the day time and at 20-22 °C at night. From American evidence, it is not poor cultivation or lack of moisture but the high temperature in the top 30 cm of the soil that hampers root growth in apples, pears, sour cherries, plums, apricots and peaches in California. In the summer, the soil in apple orchards in the Crimea and Moscow Region is mulched and in the citrus plantations in Florida it is grassed down for the same reason: to reduce the soil temperature and to provide for better root growth.

According to some authorities, the optimum soil temperature is about 12 °C for gooseberry, 15-20.5 °C for apple and 18 °C for peach, with poorer growth at any increase. For better callus formation on the cut roots of apple and peach trees the temperature of the soil should be between 29.4 and 32.3 °C.

Winter-resistance of roots. Though roots are sheltered by the soil, damage to, or destruction of, fruit plant root systems occurs not only in the northern and central zones of the U.S.S.R. where apple, pear, plum, etc., are often affected, but in the southern zones as well, damaging such species as citrus fruits, grapes, apricot, peach, almond, walnut and feijoa (F. Davitaya, 1948; I. M. Vasilyev, 1953; L. I. Sergeyev, 1953; I. I. Tumanov, 1954; G. V. Trusevich, 1957; Komissarov, 1959).

However, the death of roots on account of low temperatures is relatively infrequent, because the effect of sudden drops in temperature which are so harmful to the aerial portions of plants is very much reduced by the time the cold has penetrated to the roots. Only prolonged frosts, especially in snowless winters, can lead to root damage. Nevertheless a certain amount of root damage, which is usually not noticeable in tree growth but may adversely influence fruit formation, is done almost every year.

When apple roots have been badly damaged during the winter the tree resumes its vegetative growth in spring but the leaves and blossoms soon wilt. The tree will die soon

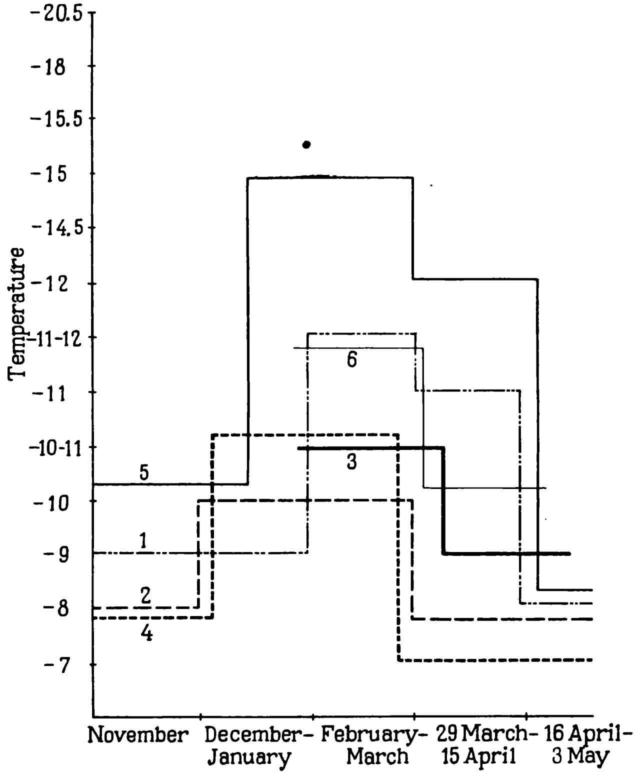


Fig. 64. Temperatures causing fruit plant root damage in different seasons:

1—apple; *2*—pear and plum; *3*—peach; *4*—sweet cherry; *5*—mahaleb cherry; *6*—raspberry and blackberry (after Carrick)

afterwards or linger on for a year or two, depending on the amount of damage (N. F. Childers, 1947).

Roots of tree and soft fruits are much less capable of standing reduced temperatures compared to branches and shoots (Fig. 64). The staggered pattern of temperatures in Fig. 64 is due to the fact that the temperature values shown correspond to the transition of plants to the winter condition (December-January) or, on the contrary, to the start of growth (March-April), when the ability for winter-resistance is rapidly decreasing. This must be taken into account in fruit plant care.

The absorbing roots of fruit plants are highly susceptible to freezing.

Using the method of direct freezing, I. A. Muromtsev (1963) obtained data on the frost-resistance of absorbing roots in 12 tree and soft fruits which are presented in Table 11.

Table 11

Frost-Resistance of Absorbing Roots of Tree and Soft Fruits

Species	Temperature in degrees Celsius		
	slight damage	extensive damage	death
Black currant	—3.1 to —3.6	—3.6 to —4.7	—4.7 and lower
Raspberry	—2.8 to —3.5	—3.5 to —4.2	—4.2 and lower
Strawberry	—2.1 to —3.1	—3.1 to —4.0	—4.0 and lower
Gooseberry	—1.9 to —2.5	—2.5 to —3.2	—3.2 and lower
Plum (Italian)	—1.8 to —2.5	—2.5 to —3.6	—3.6 and lower
Apple (seedling Antonovka)	—1.8 to —2.1	—2.1 to —3.0	—3.0 and lower
Blackberry (Izobilnaya)	—0.9 to —1.2	—1.2 to —1.9	—1.9 and lower
Grapes (European)	—0.5 to —1.0	—1.0 to —1.8	—1.9 and lower
Filbert	—0.7 to —1.0	—1.0 to —1.7	—1.7 and lower
Avocado	—0.9 to —1.2	—1.2 to —1.9	—1.9 and lower
Peach	—0.9 to —1.2	—1.2 to —1.8	—1.8 and lower
Lemon	—2.8 to —3.7	—3.7 to —4.0	—4.0 and lower

The degree of damage varies with species, rootstock, depth of distribution and thickness of roots, period (growth or dormancy), soil (moisture, etc.) and cultural practices.

Thick roots are more frost-resistant than thin roots. The roots uncovered during summer are usually hardier than those remaining in the soil. The degree of frost-resistance varies from tissue to tissue too. For instance, the meristem tissues, which have an alkaline reaction (pH=8), are more resistant to low temperatures than those with an acid reaction (pH=6.1-5.4), including the tissues of the bark (pH=6.1-7). The tissues of the central cylinder of the root with a neutral reaction (pH=7.3-7.9) have a medium resistance. It is very likely that the death of absorbing roots in the surface layers of the soil is a common occurrence but it does not seem to involve great numbers of roots or any

substantial damage to the tree. Death of absorbing roots was reported in the central zone of the Russian Federation (A. V. Morozov, 1956), in the Ukraine (A. S. Andrienko, 1955) and in Georgia, U.S.A., on pecans (W. Woodroof and G. Woodroof, 1934).

Shallow-rooted fruit trees such as plum, sour cherry and filbert and fruit trees on dwarfing stock such as apple or quince are more liable to freezing injury of roots than the more deeply rooted species, e.g., pear, sweet cherry and walnut.

Frost-resistance also depends on the species of rootstock used. For instance, the roots of the Chinese apple are hardier (—12°, —16°C) than those of *M. sylvestris* (—10°, —14°C). The death of the cambium results in the death of the root. The frost-resistance of roots in the case of seedling rootstock varies with the depth of their distribution and their age period. It decreases in the downward direction and towards the outer boundary of the root system (G. V. Trusevich, 1952).

A drop in temperature to —13.4°C at a depth of 20 cm was registered in 1910 in Moldavia. On such occasions, particularly if they fall on a snowless beginning of winter, roots may be damaged as was observed in Moldavia in 1910.

As observed in New Hampshire, U.S.A., soil was frozen down to 40 cm deep in March when fallowed, to 30 cm when grassed and only to 25 cm when well-manured and cover-planted (G. H. Gourley, 1927).

Fruit plant roots may be damaged and killed at the beginning of winter when there is as yet no snow, and the temperature has droped to —30 or —40°C. This was not infrequently the case on large areas in the central and southern zones, and especially so in the middle zone during the winter of 1938-1939. Had the ground under the trees been covered before the snowfall with manure, straw, sawdust or other material the trees would have been saved. Autumn irrigation is also essential, especially in years of drought.

Water

Like light and temperature, water is one of the main factors of successful growth, development and cropping of fruit plants. It is a component of all plant tissues. There

is from 50 to 75 per cent of water in leaves and shoots, 60 to 85 in roots and 85 and even more in fruits. Water dissolves nutrient substances and transports them all over the plant, maintains the indispensable turgor in plant tissues, regulates the thermal condition of plants, participates in the structure building and life-activity of cells in all plant tissues. When water in plant cells is in sufficient supply the processes of synthesis predominate, while lack of water, i.e., dehydration, results in the stepping up of the processes of hydrolysis. The normal flow of all physiological processes in plants can only be ensured by a regular supply of water.

The water regime in plants depends on (a) size and structure of the portions of the plant below and above the ground, the rhythm of their life activity (growth and rest) and the water requirements of the plant; (b) the amount of precipitation and the humidity of the soil and air, and (c) conditions of the water intake and consumption by plants.

Precipitation. When there is no irrigation the main source of water for plants are precipitations in the form of rain, snow, fog, dew and hail. They contain weak solutions of nitrogen-ammonium and carbon-ammonium salts and of carbonic acid. According to I. Sanson (1945), 1 litre of rain water in France contains between 1 and 2 mg of nitrogen. There is two or three times as much nitrogen in snow. Every extra two tons of fruit harvested require an increase in precipitation of 50 mm per hectare (R. C. Thompson, 1940).

Ecologically, the decisive factor is the overall moisture balance, i.e., the ratio between the amount of water a plant is able to take in and the amount of water the plant gives out in transpiration. For normal plant life this ratio cannot drop below unit for any prolonged period of time (H. Lundegardth, 1930).

The favourable effect of summer precipitations depends on their intensity and frequency and on the type of soil. Precipitations are subject to rapid and strong evaporation. Thus, according to A. Bechtle (1908), precipitations of 2-13 mm are completely evaporated from the soil in 2-14 days and those of 25-50 mm, in 20 days (68-85 per cent). In addition, tree foliage retains up to 30 per cent of precipitations even in an average rain. It is essential that rainfalls

are plentiful and occur when they are needed by fruit plants but this seldom happens in nature.

In the European part of the U.S.S.R. precipitations sharply decrease from north to south. For instance, the first three months of vegetation bring in the Kaluga Region an average of 221 mm, in the Tula Region 204 mm, Kursk Region 147, Ryazan Region 164, Penza Region 160, Ulyanovsk Region 146, Saratov Region 115, Volgograd Region 104 and Astrakhan Region 58. These facts by themselves have shaped fruit-growing methods in these areas.

For successful growth and cropping fruit plants are generally considered to require an annual 700-800 mm of precipitations falling at the appropriate phases of growth. Most areas of the U.S.S.R., both in the European part and in Siberia and Central Asia, only get between 250 and 500 mm, very irregularly too, so that irrigation is indispensable for high annual yields.

Snow as a form of precipitation is essential too, both for replenishing the reserves of water in the soil and protecting roots from freezing injury during harsh winters. In some areas tree fruits are liable to be damaged by hail. In such cases shoots and branches may be broken or bruised, which leads to local necrosis of cambium and bark tissues. Hail-damaged fruit develop corky dents or scars, and become unmarketable. Sometimes branches get covered with ice, which may cause breakage and bud or bark damage. Fogs common in some coastal areas in the Crimea and Caucasus are injurious to pollination because pollen grains tend to germinate and perish during flowering.

Fruit plants can be placed in the following order according to their water requirements: quince highest, then plum, apple, pear, walnut, sweet cherry, peach, apricot, mulberry, almond, pistachio. The last three species are the most drought-resistant ones. Water requirements in different varieties of the same species vary within wide limits.

Under irrigation in the Crimea immature apple trees had delayed fruit-bud formation by 7 to 10 days, sustained it longer and developed more leaf initials than trees without irrigation (I. S. Rudenko, 1958).

Water consumption by fruit plants is highest in the spring and early-summer period, at the time of flowering and of vigorous shoot and root growth, then it falls off a little until early autumn, when it increases again, espe-

cially in the conditions of heavy cropping and autumn and late-autumn root growth.

Transpiration. Transpiration, or loss of water vapour, is essential for the growth and cropping of fruit plants. When it increases, carbon assimilation increases too, with a resultant accumulation of dry matter. It is important that fruit plants always have a sufficient supply of water—whether in the form of precipitation or irrigation. It is also important that fruit plants meet winter with a sufficient reserve of water because not infrequently trees do not have enough water to provide for transpiration in the winter period. According to L. H. Bailey, an established apple tree loses 250-300 g of water daily during the winter. L. A. Ivanov (1953), who studied transpiration in 60 wild and cultivated woody plants in the Leningrad Region, believes that their possible introduction into more northerly areas and into mountains depends to a large degree on their transpiration rates during the winter. Such introduction is mostly possible with those species, which have a less pronounced capacity for transpiration. Observations in North Dakota, U.S.A. showed that trees growing on close-textured soils with an insufficient supply of water in the autumn display desiccation of tissues before the winter begins which weakens the resistance of the trees to further desiccation (C. V. Waldron, 1901).

Certain workers believe that the northern line of woody plants is determined first and foremost by the amount of their transpiration in dormancy.

Excessive loss of water by fruit tree tissues may also occur in the most ordinary winter conditions. This is particularly characteristic of the south-eastern areas of the Russian Federation. It occurs after a droughty summer and especially after a similar autumn too, during which there is little or sometimes no root growth. Consequently trees are unable to store the amounts of water necessary for normal winter transpiration, let alone an excessive transpiration during a windy winter. In such cases the weakened tree and soft fruits are an easy prey to freezing injury under normal winter conditions. This is the reason why it is important to irrigate orchards in the autumn and even in the winter (in the south) when there has been no substantial rainfall, and also to plant shelter belts.

Lack of water in the soil is injurious to fruit plants as it produces in them the state of physiological drought which is increased when there is a wind or sharp increase in the air temperature. A certain deficit of water in plants, particularly in their leaves, is common even in the optimum supply conditions because in the day time leaves may transpire more water than they receive from the roots. This may even lead in the south to leaf necrosis, e.g., on Beurré Diel pear trees.

As most of the water is taken up by a fruit plant through its absorbing roots, it is essential to know how the state of the supply of water influences their growth and development.

According to recent studies made by I. A. Muromtsev (1963), absorbing roots in drought conditions stop growth 1 to 3 days before leaves begin to wilt. As roots stop to grow they become suberized rapidly, following which (or simultaneously with which) wilting begins. In I. A. Muromtsev's view, his findings are in direct contrast with those of A. H. Hendrikson and F. Y. Weihmeier (1929, 1936) who believed that water in the soil is equally available to fruit plant roots within the wide limits from field capacity to wilting humidity. It was found that absorbing root growth in plants reduced to wilting and then watered was resumed in three days in figs and in 9 to 11 days in apples. Air drought has a strong adverse effect on the growth and development of absorbing roots. Even a brief lowering of the humidity of the air (from 90-80 to 60-50 per cent in I. A. Muromtsev's laboratory experiments) brought root growth to an immediate standstill which lasted up to 3 to 4 days with some of the tips dying off.

Droughts occur not only in the south and in the Volga area but also in the nonchernozem zone. For instance, in the conditions of the relatively small precipitations of 500-600 mm a year in the Moscow Region droughts of 16 to 20 days long occur once every two years and of three weeks and more, every four year.

Droughts in August and September result in damage to trees, particularly of the winter varieties. Their fruit tend to shrink and drop. Of the apple varieties grown in the Kuban area, most susceptible to droughts were Reinette de Champagne, Rosemarine Blanche, Winter Golden Pearmain, Sary Sinap (A. K. Priymak, 1957).

According to N. A. Maximov, drought-resistance means the ability of plants to withstand droughts, i.e., to revert easily to their norm after prolonged wilting with a minimum damage both to the plant and to its crop.

Lack of water in the soil leads to poor shoot growth, leaves do not develop properly and the period of root growth shortens. All this results in reduced cropping and poor-quality fruit.

An excess of water, particularly when leading to waterlogging, is highly injurious to trees. The more water there is in the soil the weaker its aeration, i.e., penetration of air into the soil. Moreover, the excessive water forces the air, which is indispensable for plant breathing, out of the soil. In anaerobic conditions the active parts of roots begin to die back, water and nutrient intake discontinues and the tree perishes though there is plenty of water in the soil.*

A temporary excess of water in soil may lead to a standstill in shoot growth and the death of a part of leaf surface. This was observed in the Crimea in 1932, 1933 and 1940 when heavy spring rainfalls retarded the start of growth of certain roots and caused the death of others in the parts of orchards with the soil lacking in firm structure and a favourable water and air regime. Subsequently, this resulted in the fall of newly formed leaves and ovules.

In the optimum conditions of water and air in the soil the surface of conducting roots is light brown in colour; as the conditions worsen the roots darken, then they become black with a bluish tinge, the cortex on them cracks or bloats in places and dies off. These visual signs of a gradual change in the state of root cortex can be used as an easy indication of the state of roots and the water regime of the soil in an orchard (Fig. 65).

Two remarkable instances of large-scale root death were recorded by the author in the Crimea, in the Primorye State Farm (near the Sivash) and especially in the Comintern State Farm apple orchard where spring floods caused silting in the river bed and, as a consequence, the water-table under the orchard was raised (Fig. 60).

According to A. Lecrenier and E. Dermin (1955) and others, the pathological consequences of an excess of mois-

---

* This condition is commonly referred to in English fruit-growing literature as "The Death"—Tr.

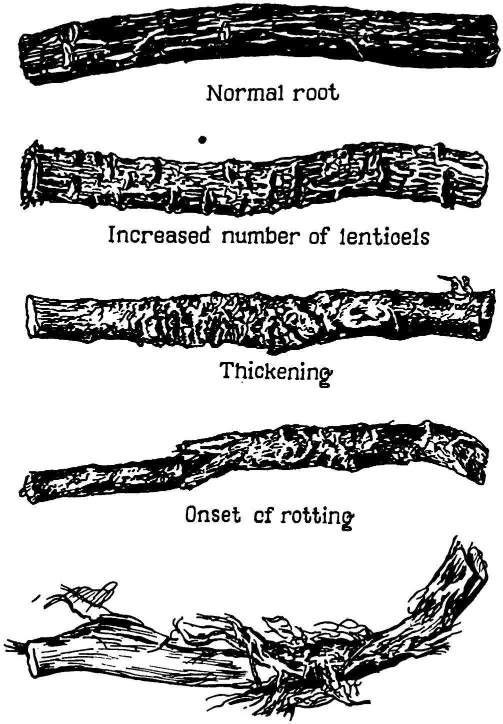


Fig. 65. Effect of excessive moisture in soil on apple roots

ture include: (a) splitting of fruits, particularly sour cherry and plum, and, to a certain extent, apple (also sweet cherry in the Crimea and gooseberry in the Moscow Region); (b) overgrowth of certain tissues, more often of the stem; (c) chlorosis, certain virus diseases and gummosis in stone fruit. Lack of moisture in the soil brings about a splitting of stones in peach and plum, and scorch, curling, yellowing and falling of leaves, etc.

Fruit trees can easily survive flooding in autumn and winter, which sometimes happens in floodland orchards, for periods of one or two months or even more. This is due to the absence of root growth in the resting trees and the constant movement of water.

To eliminate an excess of water in the soil the techniques of drainage and grassing are used. Moreover the regulation of the water supply is an indispensable part of general orchard management aimed at regular high crops.

Air

The air plays a vital part in the life of fruit plants. Two of its components are of particular importance: carbon dioxide which is utilized by plants to build up organic substances, and oxygen used in respiration by the root and aerial portions of plants. In addition, the root system requires good water and air conditions to keep the leaves well supplied with carbon dioxide. Investigations of B. N. Makarov (1956) showed that from 38 to 70 per cent of the carbon dioxide a plant needs for its photosynthetic activity comes from the soil.

The annual pattern of the oxygen and carbon dioxide content in the soil is shown in Fig. 66. As can be seen from it, the oxygen content in heavy soils is usually low in early spring and rises by the beginning of the summer. The carbon dioxide content normally reaches its peak in summer when the soil temperature and the level of moisture favour biological activity. The minimum oxygen content and the maximum carbon dioxide content do not coincide in time.

In D. A. Sabinin's opinion (1955), poor aeration of the soil not only puts a stop to water and nutrient intake by a plant but can also cause the roots of the plant to excrete water and nutrients into the soil.

Of all the different kinds of roots, absorbing roots and root hairs are the most sensitive to a lack of oxygen.

I. A. Muromtsev (1955, 1963) showed by his experiments that in mediums with low oxygen content absorbing roots and root hairs develop poorly, while new ones do not develop at all, which brings about a sharp reduction in the overall absorbing surface of the root system. Moreover, the epiblema of such roots loses its ability to develop new root hairs, even after the restoration of a normal gaseous regime. Without oxygen, there is no new formation of either absorbing roots or root hairs while the existing ones stop growing and perish.

After a 30 minute immersion into a medium completely lacking in oxygen no new root hairs appeared on the grow-

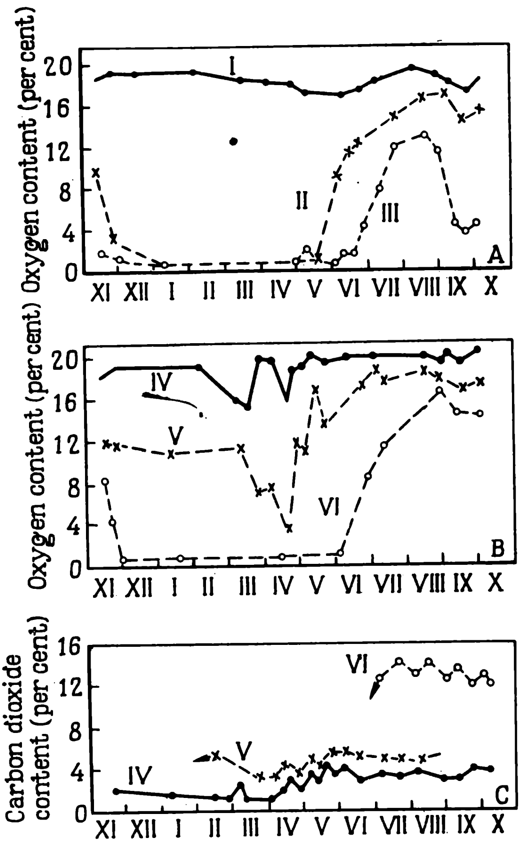


Fig. 66. Changes in oxygen and carbon dioxide content in orchard soil throughout the year (after Boynton and Reutor):

A—Influence of the mechanical composition of soil on oxygen content at depth of 1.5 m; *B*—oxygen content at three depths in large-silty heavy loam; *C*—carbon dioxide content at three depths in silty loam. *I*—light loam; *II*—large-silty heavy loam; *III*—silty clay; *IV*—30 cm deep; *V*—60 cm deep; *VI*—180 cm deep

ing parts of a root system. Poor aeration inhibits root hair development to a greater extent than absorbing root growth (I. A. Muromtsev, 1955).

The wind is also an important factor in fruit growing. Constant movement, or exchange, of air in the heads of trees is beneficial for their growth and cropping. The winds may be strong and dry and, hemmed in by mountains or

hills, may sometimes develop into storms that desiccate trees, particularly in winter, and shake off the crop in summer. Winds hamper the flight of honey-bees, dry up the nectar in flowers and the stigma on the carpels, thus decreasing pollination and fertilization.

Moderate wind is beneficial for nut trees which are pollinated by wind carrying pollen during blossom time. Moderate wind is also useful in obviating spring frosts. To fight strong winds, shelter belts and windbreaks are planted.

Requirements of Fruit Plants for Mineral Elements and Nitrogen

Besides carbon, hydrogen, oxygen and nitrogen, fruit plants require various mineral elements, including trace elements, for normal growth, development and cropping.

M. Y. Shkolnik (1950) proposed the following classification of the elements required by plants:

(1) structural elements—carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus and magnesium;

(2) elements forming part of biocatalysts—iron, copper, zinc, manganese and cobalt;

(3) other indispensable elements—potassium, calcium, boron, molybdenum, and, for certain plants, silicon, helium and aluminium, which are neither structural nor part of biocatalysts, but without which plants cannot develop normally;

(4) radioactive elements—uranium, thorium, radium, actinium, rhodium;

(5) stimulators—sodium, chlorine, arsenic, titanium, cobalt, nickel, iodine, bromine, rubidium, etc.

It should be pointed out here that nitrogen forms part of the protein molecule, cell vacuoles and chlorophyll which is responsible for photosynthesis. That is why a shortage of nitrogen leads to a deterioration in protein synthesis, to the use of reserve nitrogenous substances stored in the stem, roots and branches, bringing about a disruption of the entire life activity of a plant.

As reported by P. K. Ursulenko (1937) of the Mleyevo Fruit-Growing Research Station, the weight of the aerial portion of apple seedlings grown under glass showed a greater increase in all variants with nitrogen than the weight of the

root system. Thus in the nitrogen and phosphorus (NP) variant the weight of the aerial portion was 133 per cent and that of the root system 7 per cent greater than in the control plants. In the nitrogen, phosphorus and potassium (NPK) variant this increase was 50 and 13 per cent respectively, i.e., the weight of the aerial portion had increased less as compared with the root system. The apple root system produced more fibrous root in the variants with nitrogen.

In the presence of phosphorus and potassium different forms of nitrogenous fertilizers act differently. Ammonium nitrogen tends to lengthen shoot growth and somewhat reduces fruit-bud formation. On the contrary, nitrate nitrogen does not lengthen shoot growth in the second half of the summer and actually increases fruit-bud formation.

S. S. Rubin (1949), who studied the root system of Pippin Litovsky apples, found that after the application of nitrogen there were three times as many rootlets on a 1 cm section of a main root than in the variants with phosphorus and potassium and in the controls. According to I. I. Kolosov's findings (1950), nitrogen stimulates first of all the growth of absorbing roots and then of axial ones. A shortage of nitrogen reduces absorbing root growth. Nitrogen may increase the weight of roots by 50 per cent, in which case their absorbing surface will increase 200 per cent. Applications of nitrogen will also increase top growth.

Investigations conducted by A. K. Priymak (1951) in the Krasnodar Territory showed that even on the local rich chernozems the application of fertilizers, both mineral and organic, favourably influenced root growth in apples, plums and apricots (Figs. 67 and 68).

Phosphorus is found in the cell nucleus; it takes part in carbohydrate metabolism and is essential for the normal flow of enzyme processes. In short, the life activity of plants can proceed normally only in the presence of sufficient amounts of phosphorus.

According to I. I. Kolosov (1962), phosphorus promotes the branching of the root system, i.e., the appearance of lateral roots. A shortage of phosphorus leads to slow and stunted growth of the aerial portion. Plants in the beginning of their development must be provided with good phosphate nutrition.

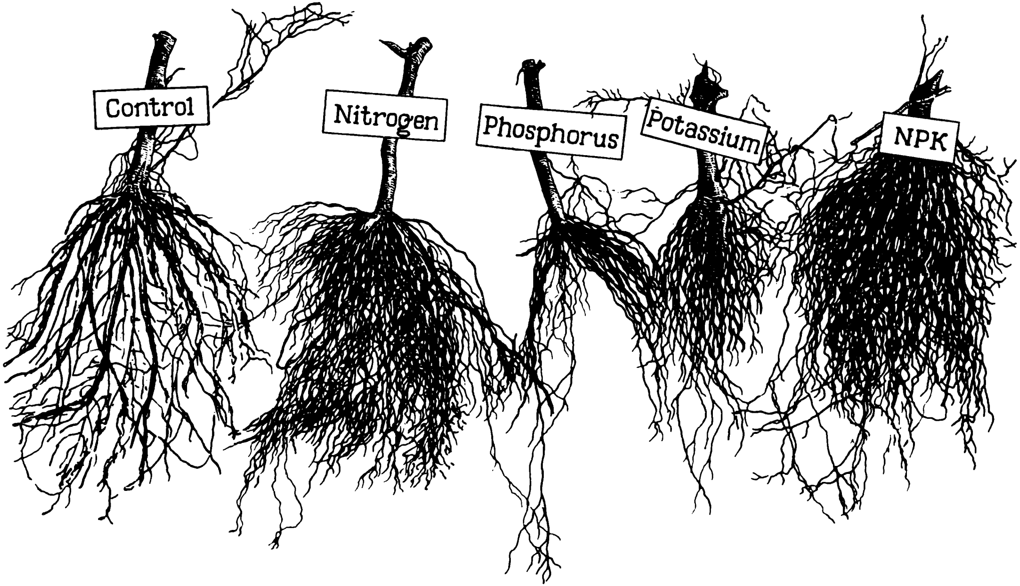


Fig. 67. Effect of various chemical fertilizers on plum root growth (after A. Priymak)

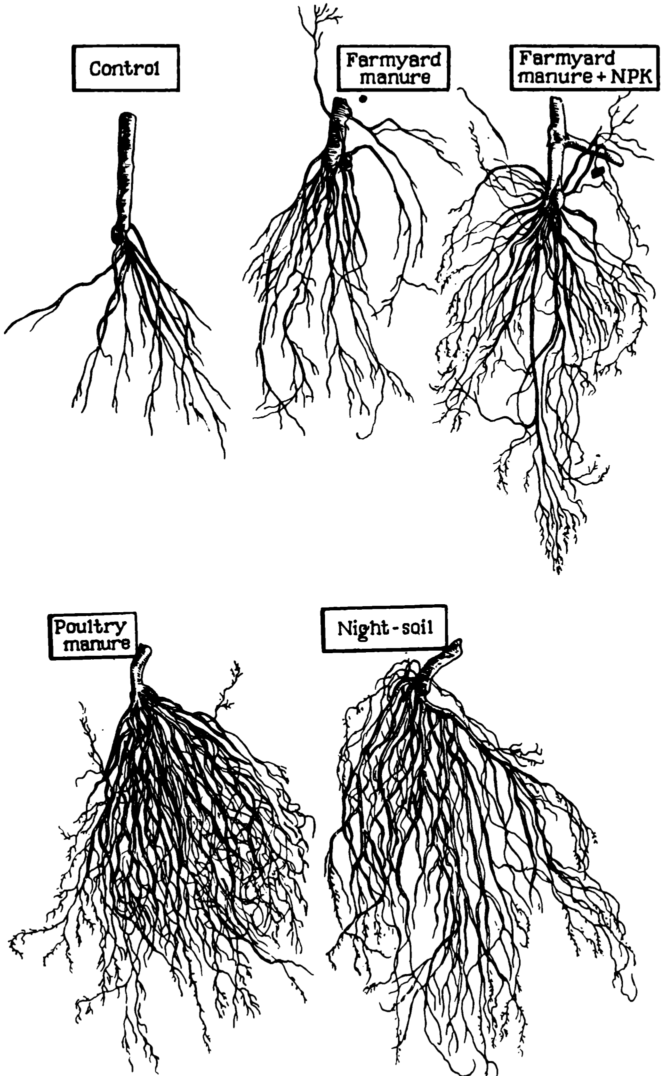


Fig. 68. Effect of organic fertilizers on root growth (after A. Priymak)

Potassium participates in the process of the assimilation of the carbonic acid and the transport of carbohydrates in plants, contributes to the essential swelling of protoplasm colloids and helps to increase nitrogen intake and the synthesis of protein compounds. Potassium, too, encourages the branching of roots. It helps to increase the weight of the roots rather than the aerial portion. Shortage of potassium acts as a brake on root branching.

Calcium forms compounds with pectin substances, imparts strength to root epidermis and the outer layers of the protoplasm. It is especially needed in the cell division region of all roots. Calcium deficiency brings about decomposition of root epidermis; roots become mucous, the growing zone and lateral roots rapidly die off (M. K. Domontovich, 1921).

The trace elements—manganese, boron, copper, zinc, molybdenum, etc.—exert a varied and powerful influence on a number of vital processes in plants, resembling in their action plant enzymes. It has been shown, for instance, that the enzyme processes involving proteins can only occur in the presence of zinc, magnesium and certain other elements (A. P. Vinogradov, 1938), young plum trees react favourably to the dressings of molibdenum (D. R. Hoagland, 1950); manganese is essential for lemon growth (N. A. Makarova, 1956), etc.

A study into the causes of the rosette condition in apples in the Volga area revealed a zinc deficiency which was remedied by annual triple sprayings of the sulphate of zinc (V. M. Tarasov, 1962).

Experiments conducted in Azerbaijan from 1958 to 1960 showed that the application of various trace-elements in late April at the rate of 4-8 kg per hectare each increased yields of fruits by 5.35-16 per cent. The best results were obtained by the application of higher doses of Mn, B, Co and Mo compared to Zn and Cu (I. N. Bunyatov, 1961).

F. Skoog (1940) and D. I. Arnon (1949) reported that phosphorus is part of some enzymes and participates in the formation of others. Magnesium is combined in the molecule of chlorophyll. Iron is required in the plastids for the production of chlorophyll. Zinc, copper, manganese, boron and molybdenum are thought to activate certain enzymes or to be combined within the prosthetic group which activates them. Copper and manganese are part of certain

enzymes, while zinc seems to protect the auxin against the too-quick disintegration in plants.

Plants contain 1-2 per cent green weight (6.5 per cent dry weight) of mineral elements and nitrogen. Though this amount of minerals taken out of the soil is negligible in weight its importance is enormous, for without it growth and fruit bearing cannot proceed.

The content of ash elements and nitrogen in the bark is much higher than in xylem. The fruits have small amounts of ash elements, 0.3-0.4 per cent, but with high yields a considerable quantity of them is taken from the soil. For instance, the three main elements—nitrogen, phosphorus and potassium—are amassed in the fruits of a high yielding tree in much greater quantities in the course of one season than in the trunk, branches, leaves and roots taken together.

It is interesting to quote the estimations of W. H. Chandler (1957) regarding plant requirements. He considers that on an area of one hectare with the yield amounting to 22.5 tons per hectare (which is lower than the average for apple, pear and peach in the best areas and higher than the average for apricot, plum and sour cherry), the fruits, leaves and current growth may contain about 33.5 tons of water, about 13.5 tons of organic and 0.7 ton of mineral substances. As regards the amount of water in fruits, leaves and wood it is only a fraction of the amount of water that trees take up from the soil in one year. In fairly dry areas one hectare of orchard appaiently takes up some 4,480 tons of water annually, including about 40.3 tons which are transpired by the leaves. In the author's opinion, one hectare of orchard has about the same amount of organic and nonorganic substances in the root systems of trees. Altogether highly, and particularly annually cropping fruit trees require plenty of ash elements. Regular fertilizing and top-dressing is therefore essential.

The normal growth and cropping of fruit plants can only proceed when they are provided with the necessary amounts of all the food elements. Both shortage and excess of individual trace-elements affect the life activity of plants which is shown in Table 12. According to M. N. Yazvitsky (1940) and other workers studying gooseberry, a deficiency of nitrogen in it is revealed by a pale-green colour of leaves and at leaf margin a lilac colour of the

Table 12

Effect of the Lack and the Excess of Elements, Including Trace Elements, on the Growth and Development of Fruit Plants
(after T. Wallace, J. Russell, N. F. Childers, M. N. Yazwitsky and others)

Element	Symptoms of lack of an element	Symptoms of excess of an element
Nitrogen	Sharp decrease and discontinuation of extension growth of shoots and roots; poorer flowering and cropping; fruits immature and drop; yellowing of leaves and early defoliation; buds drop and branches become bare	Excessive vegetative growth, poorer flowering and fruit formation
Phosphorus	As for nitrogen deficiency, but fruits of poor quality and markedly acidic	Too early maturing and deficiency of certain elements (potassium, iron and zinc)
Calcium	Shoot growths die back, pedicels wilt and root growth is inhibited; apple leaves are damaged and stone fruits develop gummosis	Potassium, magnesium, zinc, manganese and boron deficiency
Magnesium	Chlorosis and defoliation, fruits fail to ripen in apples; chlorosis in raspberry	Calcium deficiency
Potassium	Leaves show marginal browning and tints; fruits small and often immature	Deficiency of calcium, magnesium and, possibly, manganese; appearance of leaf scorch
Sulphur	As for nitrogen deficiency; also leaves turning yellow in citrus fruits	Excess of sulphur in the soil is a rare occurrence
Sodium	— —	Calcium deficiency; inhibition of plant growth

(continued)

Element	Symptoms	
	of lack of an element	of excess of an element
Iron	Terminal leaves of shoots become chlorotic;leaves blotchy; shoot growths die back, particularly on calcareous soils	Phosphorus and manganese deficiency
Manganese	Leaves become chlorotic; apple leaves turn yellow, but veins and surrounding tissue remain green	Blotchy leaves (peach); die-back of leaves and shoots; sometimes, chlorosis
Copper	As for calcium deficiency; also shoot distortion and leaf chlorosis	—
Zinc	Shorter internodes and very small leaves (rosettes); chlorosis and necrosis of leaves and fall of old leaves; blotchy chlorosis in citrus fruits	Iron deficiency and partial leaf necrosis
Boron	Deformation of meristem tissues and shoots, with necrosis of growing points and pitting of flesh in fruits, particularly in apples; fruit-drop	Browning of old leaves; gummosis on citrus leaves
Molybdenum	Chlorosis and poor leaf growth, poorer nitrogen-fixation by azotobacter; shoot growths die back; yellow spots on citrus leaves	Tints on leaves
Chlorine	—	Browning and shrinking of leaves as in potassium deficiency (red currants)
Aluminium	—	Shoots and leaves as for phosphorus deficiency; roots develop poorly and have few root nets

leaf margin turning into a dark fringe; of potassium, by marginal browning; of magnesium, by red stripes on the edges of leaves.

Potassium deficiency in currants leads to leaf scorch and irregular fruit ripening, conspicuously in black currants. The same deficiency in raspberries brings about leaf browning and curling, while lack of iron and magnesium results in chlorosis. Poor runner formation is registered in strawberries deficient in nitrogen and phosphorus; leaves are pale green when deficient in nitrogen and turn purple when this deficiency is acute.

A wealth of information on the correlations between the amount of nutrients, particularly nitrogen, phosphorus and potassium, found in the soil and in the leaves has accumulated in horticultural literature. In many countries (U.S.A., Holland and others) the technique of foliar analysis is now used to provide a basis for practical recommendations on the nutrition of tree fruits.

It can be seen from the above that fruit plants are very exacting as to nutrient substances, both in quantity and in composition, particularly during the years of heavy crops. Moreover, the richer fruit plants themselves are in nutrient substances, the more young wood, particularly new growths and young spurs, they have and the longer the active roots grow, especially in the autumn. In this period tree can store up considerable amounts of nutrient substances and water which will ensure a better winter-resistance and subsequent flowering, and ovule and fruit formation.

Soil Factors

G. I. Gruzdev (1960) summed up his long-standing studies of the problem of the analysis of soils for orchards in the following way:

(1) soils for orchards highly intensive and occupied by long-lived fruit plants require a detailed and comprehensive prior examination of their qualities;

(2) the establishment of an orchard always involves a considerable outlay of capital and labour and so an incorrect estimation of the soil conditions of the site will lead to a considerable loss;

(3) the qualitative suitability of a site must be estimated with a view to its continuous use for 30-60 years for

pome fruits, 25-40 years for stone fruits, 15-20 years for bush fruits and up to five years for strawberry;

(4) the examination of the suitability of the soil must be carried out with due allowance for the individual character of the root systems of various fruit plants and of the depth of distribution of the bulk of their mass, viz., down to 2-3 m for the pome and stone fruits and 1-1.5 m for the soft fruits.

The author believes that the first indication of the suitability of soils can be seen in the way the root systems of cultivated or wild fruit plants have developed in them.

Tree and soft fruits are rather exacting as to soils and subsoils. Soils must be sufficiently fertile, well supplied with moisture and easily penetrated by air and water. The roots of all tree fruits, and especially of apple and pear in all zones and sweet cherry in the south, run deep; that is why the depth and permeability of the soil and the height of the water table are so important for these species. A high water table and impermeable layers in the soil are deleterious to the root systems of all fruit plants and to their growth, cropping and longevity.

In the case of fruit plants the root-inhabited layer must be at least 1.2-1.5 m deep. The best soils for apple, pear and sweet cherry are those where the water table is no closer than 2-3 m from the surface, the figure for the other stone fruits being from 1.5 to 2 m.

The proximity of ground waters exerts a harmful influence on tree fruits, particularly from the moment they enter the bearing age (P. G. Schitt, 1937). This problem was studied by A. P. Chefranov (1939) and the present author (1938) in the Crimea, G. A. Kabluchko (1955) in Moldavia, E. S. Bisti (1958) in the Volga area and others.

The soil types most suitable for orchards in the northern and central fruit-growing zones are soddy, weekly-podsolized, dark-grey forest soils and in the northern zone, chestnut and chernozem soils. In Moldavia, for instance, the more suitable soil types are dark-grey and brown soils, dark-grey and grey forest soils, leached and podsolized loamy chernozems and soddy-alluvial meadow light loams.

Unsuitable for orchards are marshy, meadow-marshy and gravelly soils, and solonets and saline soils.

A. P. Dragavtsev's studies (1958) showed that apple varieties react differently to underlying gravel, a leading

variety Aport Aleksandriisky being the worst affected. When gravelly layers are very compact, apple roots cannot penetrate deep enough in the mountain-steppe chestnut soil (Fig. 69).

The soil requirements of fruit plants vary with species. The apple tree does better on deep, medium dense loams and chernozems. The pear is exacting as to warmth and prefers loose loams, sufficiently deep and moist. The plum does best on clayey soils and loams with sufficient moisture. The cherry requires planting on high ground, on relatively light sandy soils and on gravelly loams. The almond, apricot and peach prefer deep sandy and gravelly soils rich in nutrients and with a low water table.

Fruit-growing practice has to cope with neutral, acid and alkaline soils. According to their reaction to the pH of the soil fruit plants can be divided in the following way (S. Rubin, 1958):

First group, which includes species requiring neutral soils, e.g., sour cherry, plum, sweet cherry, apricot, peach.

Second group, including species which do satisfactorily in weakly acid soils, e.g., apple, pear, currants, gooseberry.

Third group, including species which can stand more acid soils (pH = 5-6), e.g., raspberry, strawberry.

G. I. Gruzdev's investigations (1937) showed that in conditions different in regard to soils, geological formation (as widely divergent as the Central Russian plain, Central Asian deserts and the mountainous areas in the Caucasus and the Crimea) and topography, salt accumulation in the soil occurs at different depths. For instance, in the soddy-podsolic zone the salts of iron accumulate in the form of ortstein concretions and ortsand solid layers which, in conditions of extreme moisture, can inhibit orchard tree growth. In the podsol soils, an excessive accumulation of CO_2 can occur and inhibit the growth of absorbing roots.

The so-called saline soils, which are a common occurrence, are accumulations of surface and underground chloride and sulphate salts (e.g., in lime deposits on the chernozem soils in the Kursk Region), carbonates, sesquioxides of iron, aluminium, etc. As presumed by P. G. Schitt (1940) and later confirmed by S. S. Rubin (1958) and I. I. Kanivets (1958), the localization of harmful sulphates round the nets of absorbing roots can cause distress in fruit

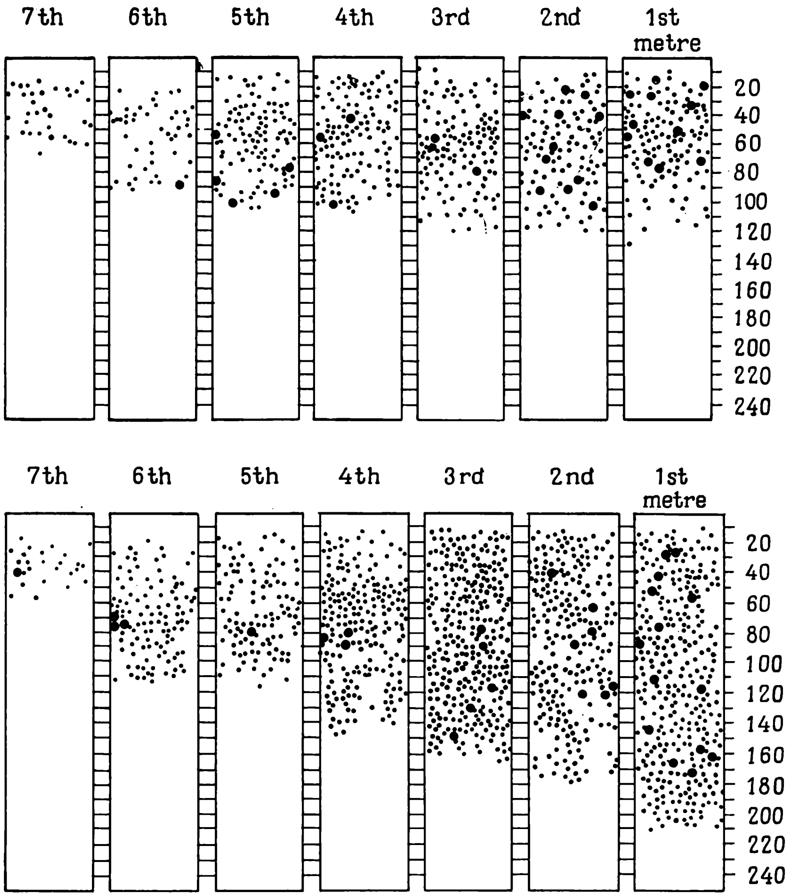


Fig. 69. Effect of gravelly deposits on distribution of 15-year-old apple tree root system:

Top row of soil profiles, with gravelly layer at a depth of 130 cm; *bottom row*, without gravelly layer (after A. P. Dragavtsev)

crops. Limestone encasings which are formed round the fibrous roots tend to inactivate the entire root system.

Salts harmful to plant life are generally Na_2SO_4, Na_2CO_3, $MgCl_2$, $MgSO_4$, $CaCl_2$. Other salts such as $MgCO_3$, $CaSO_4$, $CaCO_3$ are harmless and even sometimes beneficial as are NaCl and $MgSO_4$ if in short supply in the soil. In the majority of cases tree and soft fruits are very sus-

ceptible to excessive concentrations of salts in solution in the soil (S. S. Rubin, 1958).

The experiments conducted by D. F. Protsenko (1956, 1958) under glass showed that the least salt-resistant species were the Paradise apple (NaCl 0.25-0.50 per cent) and the Doucin (0.5 per cent). Satisfactory growth on soils with one per cent salt concentration was registered in the case of apricot, Myrobalan plum, quince and wild pear, the figure being too high for *M. sylvestris* L.

According to L. N. Gorev (1950), apricot, mulberry, peach, almond and fig can grow on certain saline soils in Uzbekistan. K. F. Kostina (1936) reports that quince can be successfully cultivated on salinized soils under irrigation.

From a series of investigations in Armenia A. P. Oganesyan (1958) concluded that fruit species can be placed in the following order starting with the most salt-resistant ones: almond, apricot, plum, pear, apple, pistachio, walnut, persimmon. He recommends using saline soils only after

Table 13

Division of Fruit Plants According to Salt-Resistance

Degree of salinization of soil	Solid residue (percentages)	Group	Species
Saline soil	2.0—3.0	I	Pomegranate, almond, apricot, plum, pear
Highly salinized . .	1.2—2.0	II	Mulberry, apple, pistachio
Medium-salinized . .	0.6—1.2	III	Peach, walnut
Mildly-salinized . .	0.3—0.5	IV	Blackberry
Nonsalinized . . .	less than 0.3	V	Persimmon

preliminary desalinization and building up of a deep cultural layer (see Table 13).

The physical composition of the soil and subsoil is also of considerable importance. Soils of the same physical composition affect fruit plants in different ways depending on the climatic conditions in which these soils are found. Subsoils of all types must first of all be sufficiently permeable to allow water to percolate freely and not to stay. This requirement of fruit plants is applicable to all areas.

The picture is different in that part of the soil where the main mass of roots is distributed. In areas where the amount of water evaporated by plants and by the ground is smaller than the amount of precipitation, fruit plants do better during a cool summer and a cold winter on sandy soils and light loams, and worse in ordinary clays and heavy clays.

Being more water-retaining and less permeable, clayey soils easily become swampy in conditions of low evaporation, particularly on gently sloping sites, which adversely affects fruit plant root growth. Then a peculiar phenomenon that may be termed physiological drought develops when roots with a more than sufficient moisture supply cannot grow because of lack of oxygen and die off. This is immediately reflected in the aerial portion of the plant; due to insufficient water intake by the roots the tops of the main limbs begin to dry.

Being more permeable and less water-retaining, the sandy soils and light loams, in contrast to clayey soils, provide better conditions for fruit plant root growth in areas with a low water table, little evaporation and high precipitation, because in this case oxygen can penetrate in sufficient quantity to enable the root system to develop normally.

A totally different situation is found in dry areas where there is more evaporation than precipitation. In those areas the clayey soils, being more water-retaining and having more moisture than the sandy soils, particularly on slopes, possess better conditions for the growth of fruit tree roots. On account of low precipitation the percolating water cannot soak the soil to a degree to cause swamping. A satisfactory aerial regime develops in the soil and the root systems are assured normal development. Sandy soils and sandy loams in dry areas, on the other hand, being more permeable and unable to retain sufficient amounts of water, provide worse conditions for fruit plant development due to lack of moisture.

In view of the significance of the soil and subsoil for the life of fruit plants a detailed soil survey should precede the siting of an orchard to assess the soil conditions in all the proposed areas. This will help to find a site best suited for planting an orchard as well as to draw up an appropriate cultural programme.

Biotic Factors

Effects of earth-burrowing organisms and earth fissures on fruit plants. Earth-burrowing organisms and particularly earthworms have a tremendous influence on the distribution of roots in the earth and, in general, on the growth and development of all plants. Thanks to the unceasing efforts of earthworms, which penetrate to great depths while passing tons of earth through their digestive tracts (according to Charles Darwin, up to 38 tons by 75,000 earthworms per hectare annually), the roots are able to utilize considerably greater volumes of soil and subsoil.

G. I. Visotsky (1899) showed that earthworms, particularly the larger species, penetrate the soil down to 8 and more metres deep. In his opinion, if there were no earthworm passages the roots would not have been able to descend so deep through the firm clay of the subsoil.

The earth-burrowing organisms, particularly the earthworms, produce prodigious numbers of passages in all soils at all depths. As recorded in the Crimea, of all the passages produced by earth-burrowing animals the ones 1-5 mm across constituted 7 per cent, 6-10 mm across 30 per cent and over 10 mm across about one per cent. The 6-10 mm, passages were considered to be made by earthworms and calculated on a per hectare basis, amounted to 600,000 to 3,000,000 (V. A. Kolesnikov, 1941).

In the Crimea, there were 950 passages per sq m of non-irrigated land 2 m below apple trees and 500 in irrigated land; there were 500 passages in areas with a water table 4.5 m deep and only 120 passages where the corresponding figure was 1.5 m.

According to data produced by the Rothamstead Experimental Station in England, there were about 1.5 million earthworm passages per hectare of unfertilized grasslands and 2.5 million on fertilized. One hectare of unfertilized and fertilized land harboured respectively 12.5 million and over 37 million insects, nematodes, crustaceas, worms and molluscs.

According to T. Rabotnov (1938), the number of earthworms in the Garshin Collective Farm in the Yaroslavl Region reached 2.5 million per hectare on dark podsolized soils. They disappeared after a prolonged application of sulphate of ammonium and increased after liming.

It is feasible and desirable to produce artificially, by means of a specially designed implement equipped with steel rods, 100-200 holes per fruit tree, in the tree spread area and 1-2 m beyond it, 2 m deep and 8-10 mm across. Such holes would undoubtedly stimulate the physico-chemical processes in the earth, facilitate root penetration and promote fruit tree growth and bearing (V. A. Kolesnikov, 1937).

Of importance for the development of root systems are also vertical fissures in the soils and subsoils. The author has observed numerous fissures 1 to 2 m deep in which the roots of fruit trees are distributed in most bizzare ways assuming shapes from cylindrical to flat down to thinnest layers.

Roots can grow inside rotten roots of other trees (Fig. 70, see root on extreme right). One can see the bark, not quite rotten, and parts of the xylem of the former root which have been used by the new roots for many years.

Rhisosphere. According to J. T. Curtis (1939) one should distinguish between (a) mycorrhiza which lives both inside roots and on them and (b) the fungi of the rhizosphere proper when the fungus covers the root as a sheath and is located between the root epidermis and the soil. Certain workers call it the peritrophic mycorrhiza. However, whereas the fungi of a mycorrhiza are symbiophytes those of rhizosphere are saprophytes.

There are always more microorganisms in the rhizosphere than in a soil free from roots. They include aerobic and unaerobic bacteria, amoeba and infusoria. All these organisms grow, multiply and die off, thus contributing to the dynamics of the soil processes during the growing season.

Plants are autotrophic organisms, i.e., they are capable of utilizing inorganic material unaided by microorganisms. However, as revealed by experiments in the sterile and nonsterile conditions with the use of the tracer technique, microorganisms produce various substances: vitamins, enzymes, growth promoting substances and amino-acids all of which stimulate root growth and development. The activity of microorganisms is at its highest in the immediate vicinity of the axial and absorbing roots of plants.

Dead roots. The dying off and renewal of the root systems of seedlings entails the dying off of thousands of roots, the corresponding figure for mature trees being hundreds

of thousands with the total weight amounting to several tons annually (V. A. Kolesnikov, 1924, 1930). As calculated by A. Y. Orlov (1955), the weight of absorbing roots dying off annually under a 25 year old fir forest reaches 2 tons per hectare. The total mass of dead roots under a fir forest and under an orchard, too, is much greater, because roots die off continuously during the growing season as well as in at least two great waves—in early spring and early autumn.

Dead roots play an exceedingly important role in the life of the soil and fruit plants, which is still underestimated by soil and fruit plant researchers.

Topographical Factors

The relief considerably influences the regular changes in the temperature of air and soil, light, the strength of wind and the amount of precipitation, thus influencing the growth, development and bearing of fruit plants. Air and soil temperatures are different on slopes equally inclined but differently exposed. For instance, the south and south-west slopes, all other conditions being equal, will invariably be warmer than those facing north, north-west and north-east. However, slopes on the southern side are drier and are characterized by sharper diurnal fluctuations of temperature which may adversely affect certain fruit species and varieties.

Parts of slopes vary in the amount of moisture in the soil, the top ones being drier than the bottom ones.

An orchard survey of various fruit-frowing zones in the U.S.S.R. conducted under the guidance of P. G. Schitt revealed that generally fruit trees do better on slopes than anywhere else. This is mostly due to a better air and water drainage.

It is considered that the best slopes are those having an inclination of 3 to 5, or at any rate, not more than 8-10 degrees. On steeper slopes, terraced planting has to be used, requiring considerable labour and capital outlay.

Small hollows cannot be used for orchards in any fruit-growing zone. For instance, during the severe winter of 1939-1940 only 4.3 per cent of trees were damaged by frost in a collective farm orchard in the Voronezh Region, while 71 per cent of orchard trees was damaged in a hollow in the same area.

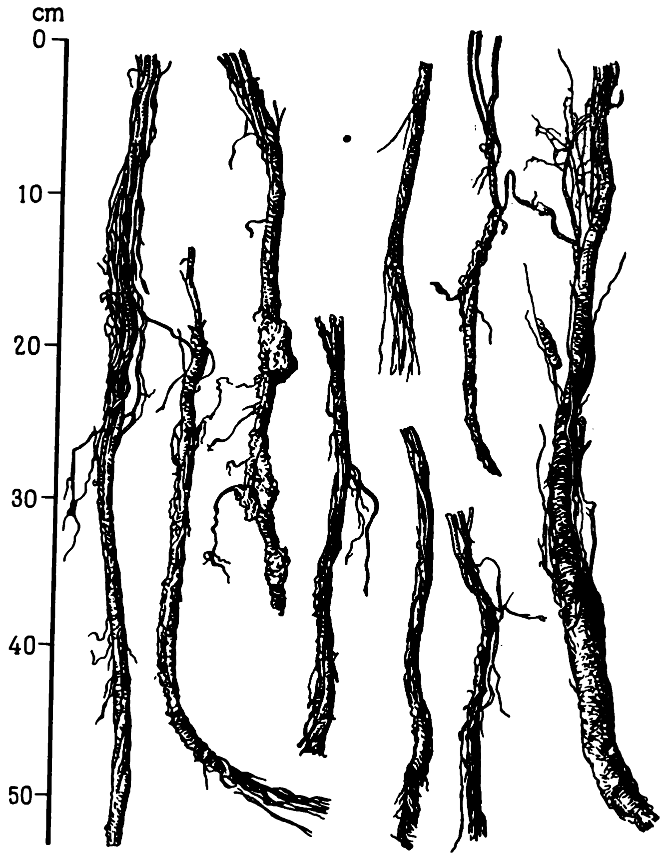


Fig. 70. Vertical roots of an apple tree (at a depth of 3-5 m)

In the northern zone the best sites for orchards are slopes facing south and south-west because they are drier and warmer, particularly the upper third of them, where there is no excess of water in the soil. Orchards can be planted on flat land provided there is good drainage and no waterlogging. Depressions cannot be used because they normally have a high water table which is injurious to the root system of fruit trees. Besides, orchard trees in depressions in this zone are injured by frosts at blooming time.

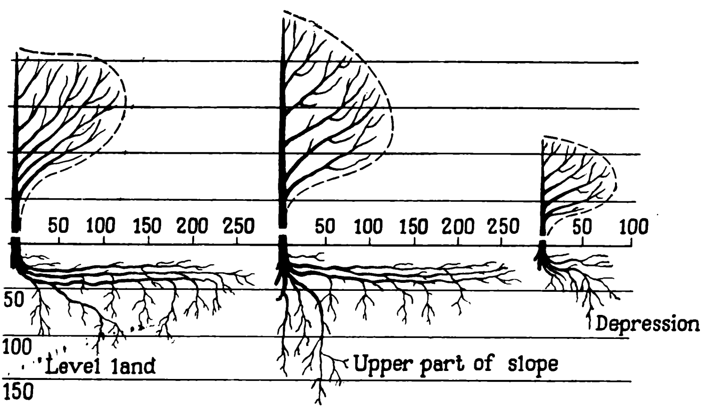


Fig. 71. Growth (in cm) of aerial portion and root system of Vladimirskaya sour cherry, the Moscow Region (after V. A. Yefimov)

Being colder, slopes facing north, north-east and north-west are totally unsuitable for orchards.

In the middle zone of the U.S.S.R. all slopes are suitable if protected by shelter belts, though those facing west, south-west and north-west are preferable being wetter. As pointed out earlier depressions, valley bottoms and hollows should not be chosen for fruit-planting sites. In such areas waterlogging and the pooling of cold air occur (so-called frost pockets). Fig. 71 provides an example by showing excavated Vladimirskaya sour cherry trees in the Moscow Region growing on 60-metre-long plots on flat land, slope and depression, in weakly-podsolized loams. The data presented graphically show the negative influence of lower parts of slopes on fruit tree development (V. A. Yefimov, 1957).

In the north-eastern zone, orchards are planted on the upper and middle parts of western, south-western and north-western slopes. Northern and north-eastern slopes are less suitable, as they are subject to the deleterious effect of dry winds. In this zone the moisture level of the soil is important; however the lower parts are risky because of the liability to spring frosts.

In the south-eastern zone, the upper thirds of western, north-western and south-western slopes are normally used because they are better protected against the dry eastern

winds. Valleys are less suitable in this zone because they are more often affected by spring and winter frosts.

In the southern zone, orchards should be planted on gentle slopes and in depressed valleys where there is less run off and irrigation is easier. It is worth keeping in mind that the southern zone is characterized by an excess of warmth and lack of rainfall.

In certain areas orchards can be planted on floodlands. For instance, the orchards in the floodlands of the Volga, Don, Medveditsa, Ilovlya, Khopyor and others are characterized by long life (80-90 years for apple trees), vigorous growth and high yields.

The same applies to lowland fruit growing in the Volgograd Region, in areas to the east of the Volga, where due to the use of melted water in the spring and appropriate cultural measures high yields averaging 12 tons per hectare have been registered in the Put Ilyicha Collective Farm in the Lenin district.

CHAPTER EIGHT

•

MAIN CONDITIONS FOR OBTAINING HIGH ANNUAL YIELDS OF FRUIT CROPS

In the U.S.S.R. as in other countries intensive research is being conducted to solve the extremely important problem of getting high annual yields in orchards. Much experimental and production material has already been accumulated and is coming under discussion not only at Soviet conferences but also at international horticultural congresses. The problem comprises numerous aspects and subects; it includes the study of the growth, development and cropping of fruit plants, the special morphological and physiological features of their fruiting and vegetative parts, the biochemical and other factors for the formation of fruit buds, the importance of varieties and cultural practices, etc.

This chapter deals briefly with the main data on the problem of obtaining high] annual yields of fruit varieties.

Special Features of Species and Varieties in Connection with Alternate Fruit Bearing

Among fruit-bearing trees of the families *Rosaceae*, *Rutaceae*, *Oleaceae*, *Ebenaceae*, *Moraceae* and *Yuglandaceae* as well as among forest trees—*Pinaceae*, *Betulaceae* and others—alternate fruit bearing is observed, which occurs under most varied environmental conditions. For example, alternate fruit bearing is most marked in apples, pears, quince, pecans, olives, persimmons and loquats; it is less marked in stone fruits, soft fruits and sweet oranges. On the other hand, in lemons, citrons and lime, which flower irregularly throughout the year, the large number of ovaries decreases the formation of new fruit buds and flowering

and reduces the harvest of next year (W. H. Chandler, 1957).

It is known that fruit crops are characterized by considerable differences in the time when fruit bearing begins. In addition, during the early years of growth of trees in the orchard, when vegetative growth of the shoots continues to mid-summer and later, they usually form few fruit buds or none at all. As the trees grow older, vegetative growth ceases earlier, which leads to increased and often excessive formation of fruit buds and a transition to alternate bearing.

In the U.S.S.R., the study of fruit bearing is carried out chiefly on apple-trees, since they occupy the leading place (over 1 million hectares), and also because in them this shortcoming is particularly marked. The effect of the habit of alternate bearing can be observed even on the best cultivated 16-hectare plot of the Chkalov State Farm (Bakhchisarai district), where 43.5 tons per hectare were harvested in 1952, 11.1 tons in 1953, 37.3 tons in 1954, 9.7 tons in 1955 and 32.7 tons in 1956.

This alternate cropping (every other year) in the fruit orchards, particularly in apple orchards, means considerable loss to the industry.

However, as shown below, there are examples of annual harvests where one year differs very little from another and in recent years there have been more and more examples of this kind.

According to H. D. Hooker's researches (1925), the total harvest from alternately bearing trees is below the harvest gathered for the same period from annually-bearing trees.

Research (carried out by Y. A. Nemirov under the author's guidance) in 1939 in the Crimea into 183 Reinette de Champagne apple-trees established that with moderate care (hoeing and watering immediately around the tree) the majority of the trees bore fruit in alternate years, while with a better background (before starting and during the experiment—three years black fallow, two years lucerne, one year black fallow, furrow irrigation, etc.), the majority of the trees, on the contrary, bore fruit annually. The trees which bore fruit annually produced a moderate number of fruit buds—from 27 to 52 per cent (the others being wood buds), but those that bore fruit alternately

produced 82 to 88 per cent in a poor harvest year. With annually-bearing trees, there was a predominance (75 per cent) of young fruiting growths (spurs)—from 1 to 4 years old; in addition, many fruit spurs from 1 to 6 years old flowered and fruited two and even three years in succession in the Moscow Region (Fig. 72). The older fruit spurs—aged 4 to 6 years and more—predominated in the trees bearing fruit alternately, since with poorer care few young fruit spurs appeared.

The average area of the leaf blade, the number of leaves on the fruit spurs, and also the total leaf area were far greater in annually-bearing trees than in trees bearing alternately.

On alternately bearing trees, fruit-bud formation began simultaneously, since these trees had, in the main, fruit formations of one type (the older spur systems); but on trees bearing fruit annually, fruit-bud formation took place over a longer period, approximately one month, since they had various fruiting growths, the majority of them being younger ones (fruit spurs and brindilles).

On the basis of P. M. Zhukovsky's suggestion (1949) that sympodia give markedly better production of fruit buds and are responsible for heavy fruit-bearing, and also of the report of I. G. Serebryakov (1953) that in some cases fruiting and vegetative shoots differ in the character of their branching, I. S. Rudenko (1950) studied types of branching in many varieties of annually and alternately bearing apple trees and established four groups of varieties—according to the character of fruit-bud formation. He recommends planting selected groups of varieties in separate plots, bearing in mind such features as capacity for mutual pollination, growth vigour, and other factors, so that their care should take into account their special characteristics.

It has been established in Rumania that varieties which put out leaves before flowering give low yields, e.g., the Ribston Pippin, the Yellow Bellefleur and other apple-trees, the Duchesse d'Angouleme and other pear-trees. The most productive varieties are those which flower before the leaves are put out, e.g., the Reinette Baumann, Boiken, Winter Golden Pearmain apples and Williams' bon Chrétien, Beurré Bosc and Beurré Clairgeau pears. The varieties of the second group are grown successfully in the

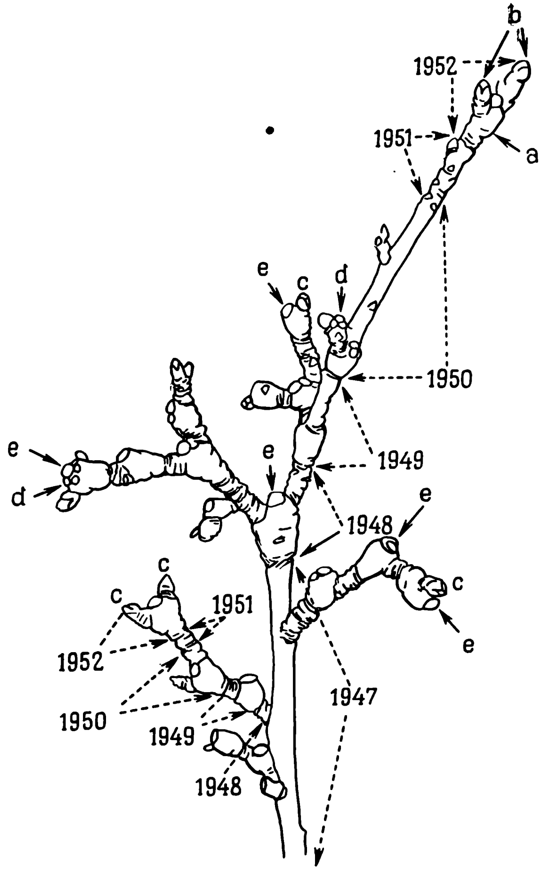


Fig. 72. Six-year-old compound fruiting branch of Titovka apple:
a—bourse; *b*—fruit bud; *c*—wood bud; *d*—mark of attachment of dropped flower or ovary; *e*—mark of attachment of fruit stem; dotted lines mark off one year's growths; judging by bourses the central part of branch cropped in 1948, 1949, 1950 and 1952, there was no crop in 1951

basin of the river Dymbovitsa (G. Moruju and Ch. Slusanski, 1959).

The formation of annual shoots on a tree is the guarantee of high yields and longevity. The annual appearance of shoots of the proper length, first of all reinforces the tree with the most productive growths—fruit spurs; secondly,

the largest leaves develop on the new shoots, having, in addition, greater photosynthetic activity than any other growths. L. Burbank considered that an abundance of roots is closely connected with an abundance of leaves and that it is possible by the foliage to determine at once whether the tree has a good root system or not.

As a result of many years of work by R. H. Roberts (1920) in the U.S.A. it was found that good conditions for growth favour annual fruit-bearing, while good vegetative growth is correlated with good fruit-bearing.

A. V. Petrov (1956) found that the longer the yearly shoots, the greater the average area of foliage on them. Our research in recent years confirms this. Consequently, in a harvest year the length of the shoots and average area of foliage both on the new shoots and on the fruiting structures are noticeably less than on trees which do not yield in the given year. The fruit grower should take this into account and by using measures of differentiated management overcome or reduce this phenomenon.

R. Magnes, F. Overley (1931) and others (U.S.A.) found that the foliage area is correlated with the growth of the tree and is the dominating factor determining the formation of fruit buds. By ringing individual branches and leaving a different number of leaves per fruit, these research workers established that there should be 40-50 leaves per fruit in order to ensure the annual fruit-bearing and the production of high quality fruit. They found that the presence of not less than 30 leaves per fruit on the tree was sufficient for the normal formation of an adequate number of fruit buds of a sufficient number of them for the following year's harvest.

Fifteen years of research in Japan on the alternately bearing Satsuma orange trees showed that thinning out in the beginning of August, 20-25 leaves per fruit being left, had a positive effect (T. Iwasaki, 1961).

I. P. Miroshnikov and L. V. Bolton (1939) found that in the Crimea an increase in the area of foliage per fruit was accompanied by an increase in the growth of all fruiting and growth structures, and also in the number of fruit buds. It was found that a satisfactory formation of buds on the Reinette de Champagne apple tree takes place with a foliage area of from 742 sq cm (56 leaves) and more per fruit, on the Sary Synap—from 534 sq cm (37 leaves)

and on the Orleans Reinette—from 377 sq cm (43 leaves) per fruit.

In the Crimea in 1953 the area of leaf surface per fruit averaged 72 sq cm in the Candil Synap variety and 186 sq cm in the Napoleon (Z. A. Metlitsky, 1956).

The following data were obtained in the author's investigations: In the orchard of the Timiryazev Agricultural Academy, Antonovka apple trees had an average of 54 leaves per fruit, the average weight of the latter being 89 grams, while at the Lenin State Farm in the Moscow Region, there were 66 leaves per fruit, the average weight of which was 159 grams. The leaves of the new growth and one-year fruit spurs were richer in chlorophyll (in July) and the leaves of the older fruit structures (fruit spurs) much less so. These data, confirming and complementing the research of Soviet and other workers, show that for obtaining a yield that is adequate in quantity and quality, it is necessary to create annually a considerable amount of 30-50 cm shoots (for an apple tree of average height) and that there should be an average of 50-75 (48-66 in our investigation) leaves per fruit.

Investigations into the question of how many leaves per fruit there should be in order to prevent periodicity in fruit-bearing, did not always lead to concordant results (Tsuin Shen, 1941). This is understandable since it is known that the amount of carbohydrates at the disposal of the tree is not always the decisive factor in the formation of fruit buds. There are cases when the leading factor is the supply of nitrogen to the tree. It all depends on which of the factors is at a minimum (F. Kobel, 1954). But, as a rule, a tree with numerous leaves not only yields better, but also produces a greater number of new shoots and young fruiting wood. Such trees, as the experience of the leading farms has proved, give higher and at the same time annual yields.

An increase in the young fruit-bearing wood usually leads to more regular and annual fruit-bearing. It has been found that good conditions promote growth in length and girth both of shoots and of fruit spurs. Depending on the conditions (climate, management, etc.) and the age of the fruiting wood, irregular growth occurs, which leads to the biennial habit in the fruit-bearing of the fruit structures. Thanks to this alternation, moderate flowering and

setting of fruit takes place and, hence, annual fruit-bearing.

The most productive fruit spurs are the young, or simple ones aged up to 5-8 years. The annual accretion of their side shoots and of the fruit spurs themselves is 1 cm or more. These productive fruit spurs and also the brindilles, each separately, often produce fruit every other year, but there is such a vast quantity of them on the tree that even in conditions of their alternate fruit-bearing, a high annual yield from the tree and orchard as a whole is guaranteed.

V. K. Levoshin (1959) established that annual fruit-bearing can take place through the alternation of fruit-bearing structures on the tree. The same thing was observed in young apple trees of the Laxton variety (W. H. Chandler, 1957).

I. I. Tumanov and Y. Z. Gareyev (1951) showed that in apple trees with an abundant harvest fruit buds are not formed as a consequence of the physiological domination of the fruits. Fruits slow down the growth of vegetative and fruiting parts and thereby hinder the formation of fruit buds in the same year.

Observations in the U.S.S.R. and other countries have shown that in a harvest year removal of the flowers on one or several main branches results in fruit buds being formed on them for the next year's harvest. Consequently, there is now periodicity of fruit-bearing in the separate branches on the tree. In other words, periodicity of fruit-bearing is rather a property of the big branches than of the tree as a whole (W. H. Chandler, 1957). This phenomenon was established also in the Sugar plum variety (M. B. Davis, 1931).

Small fruit yields occur in what are known as bad harvest years. The explanation of this is the "localization" phenomenon, when some, particularly young, fruit spurs, having sufficient foliage surface, accumulate nutritive substances in good time, making it possible for them to form fruit buds for the next year's harvest. Many people explain the small yields in the "off" years as being due to this phenomenon (W. H. Chandler, 1957).

Compound, or old, fruit spurs or spur systems, eight and sometimes up to twenty years old, often produce no side shoots but instead themselves grow several millimetres in length. Even if they do form fruit buds, the fruits do

not set. Usually few leaves develop on such fruit spurs, while the foliage area is several times less than on young fruit spurs, particularly on new growth. The task of the fruit growers, therefore, is to provide the best conditions for growth and to make use of pruning in order to promote good growth over the entire tree and thereby produce on it the essential mass of younger fruiting wood.

In the course of their evolution, fruit trees have developed and hereditarily preserved the property of forming far more flowers than are required for obtaining a yield of the necessary quantity. With the most abundant blossoming of apple and pear trees, only 5 to 15 per cent of the total number of flowers are needed for a high yield. Only a moderately flowering tree is capable of giving a high yield and laying the basis of new yield for the following year. Moderate blossoming is one of the chief conditions of annual fruit-bearing.

The biennial habit can be eliminated if various measures are undertaken which reduce the number of fruit buds setting into fruits. Many workers consider that the main reason for alternate fruit-bearing of apple trees is that in one year an excessive number of fruit buds is formed on the tree, while in another year there are too few or none at all.

A general increase in the plant nutrition by introducing fertilizers does not always give good results and alter the situation. Of chief importance here is a reduction in the number of fruit buds in the "off" year. Thus, with 80 per cent of the flowers removed in the spring, the remaining 20 per cent gave a 60 per cent higher yield than the control and, most important—40 per cent of the young fruit-spurs formed fruit buds. Pruning one- to two-thirds of the new growth produced no result (N. V. Kovalyov, 1940).

According to the calculations of the Michurin Institute of Fruit-Growing and the Fruit Station of the Timiryazev Agricultural Academy, the total number of flowers on 30-40 year old Anis Sery and the Korichnoye Polosatoye was 50,000-60,000. In the Crimea there are sometimes 100,000-120,000 flowers on Sary Synap apple trees, while approximately 1,500-3,000 fruits remain per tree.

If there is an excessive number of flowers on a tree and, consequently, very many fruit buds, then in a blossoming year there will be fewer accretions on it with a smaller

area of foliage and this will lead to the tree being unable in the same summer to form the number of new fruit buds, necessary for a harvest in the following year. A tree which, prior to this, was a regular cropper will develop the habit of alternate bearing.

Methods have now been worked out to regulate the excessive flowering by means of growth promoting substances.

Varietal Differences in Annual Fruit Bearing

I. V. Michurin long ago established that there are some varieties (e.g., his Pippin Shafranny apple variety) which form fruit buds on current growth and are therefore characterized by a constant, annual and, moreover, abundant yield. L. Burbank also considered that it is this kind of tree, which has no intervals and fruits annually, that is required.

I. K. Bessarab (1952), having studied the individual characteristics of growth and development of each apple tree separately, applied differentiated management practices to them during 1948-1951 and obtained annual yields of 11-13.5 tons per hectare on an area of 24 hectares.

It was in 1913 that P. G. Schitt distinguished three groups of apple varieties: in some, fruit-drop occurs immediately after flowering, in others—for 2-3 weeks after flowering, and in the third group almost continuously until harvest-time. The first is considered the best group of varieties because these varieties, by ridding themselves of unnecessary consumers of nutritive substances, have a greater opportunity of providing for the coming year's harvest during the same summer.

For example, the Napoleon, Orlean's Reinette and London Pippin apple varieties in the Crimea tend to bear fruit annually. In these varieties the fruit-drop occurs during 2-3 weeks after flowering. The Reinette de Champagne, Sary Synap and particularly the Candille Synap varieties have less tendency toward annual fruit-bearing, and it is in them that fruit-drop over a period of not less than 4 weeks after flowering can be observed. A similar group with a tendency towards alternate fruit-bearing occurs also in Bulgaria. These varieties discard superfluous fruits later than varieties which bear fruit annually (J. Stoichkov,

1959). Consequently, when establishing and tending trees of such varieties, this characteristic has to be taken into account.

Some research workers (V. M. Sergeyenko, 1939, W. H. Chandler, 1957) consider that fruit trees are capable of forming fruit buds on new growths during the year in which they develop. Others suggest that this can only occur where there are certain conditions in the orchard (V. R. Gardner, 1939). In Uzbekistan, there are sometimes years when on many apple-tree varieties (Rosmarine blanche, Winter Golden Pearmain, Simirenko's Reinette and others) fruit buds are formed on one-year growths and on the side shoots of fruit-spurs (N. V. Kovalyov, 1940, *et al.*).

Research work in Bulgaria (V. Velkov *et al.*, 1956) has shown that in apple-tree varieties with a tendency towards alternate fruit-bearing, such as Kichovka, Aivania, Cassels Reinette, fruit buds begin to form early—3-4 weeks after the end of the June drop, while in trees that bear fruit annually (Golden Delicious, Yellow Bellefleur, English Reinette) fruit buds begin to form 6-8 weeks after the June drop. It was found that annual fruit-bearing in varieties of the second group is favoured by the later time of fruit-bud formation, the early ending and mass character of the June drop, general vigorous growth and a spreading crown.

In many cases, periodicity of fruit-bearing in apple trees is connected with the development of fruiting growths of an identical kind, particularly annual fruit spurs of various ages, frequently older ones, and a small number of brindilles and young spurs. For example, considerable periodicity in fruit-bearing is characteristic of Antonovka, Reinette de Champagne, Sary Synap and other apple varieties because, particularly in the middle age, they primarily bear fruit spurs, the overwhelming number of which are old spur systems.

The fruiting growths of the kind mentioned above are short, weak, with little leaf surface; if they flower, they do not give high quality fruit.

In addition, in varieties where only one type of fruit-bearing prevails on the tree—e.g., perennial spurs—fruit-bud formation occupies a very short time, which is difficult for middle-aged, and still more so for old fruit trees to achieve. For this reason the latter frequently have to

switch to alternate fruit-bearing. In this case, as pointed out above, good nutrition and heavy pruning of the head can assist.

Characteristic of the other group of varieties (Pippin Shafranny, Snezhny Calville, London Pippin, Napoleon, Slavyanka, etc.) is the mixed type of fruiting growths. Usually they have fruit spurs of various ages, many brindilles and a much greater tendency towards annual fruit-bearing. In addition, if these varieties have gone over to alternate bearing, they are more easily changed to annual bearing. It is more difficult to change the varieties of the first group to annual fruit-bearing. By the use of manure, irrigation and other cultural measures, however, annual yields are obtainable from varieties of both groups.

At the Crimean fruit-growing station (V. M. Sergeyenko *et al.*, 1939) it was found that the alternately bearing Sary Synap apple had 84 per cent fruit buds in 1934, and the Reinette de Champagne 92.8 per cent, out of the total number of all buds, including vegetative. In the annually bearing apple-trees of these varieties there were respectively 48.4 per cent and 63.1 per cent of fruit buds, but in the regularly bearing Winter Golden Pearmain variety there were 58.3 per cent of fruit buds in one year and 39.8 per cent in another. Some research workers consider that fruit trees should be given conditions for moderate flowering in which the numbers of fruit and wood buds are roughly equal.

All those who have studied the leading orchards agree that some varieties are easier to switch to annual fruit-bearing and others more difficult; in one region some varieties tend to produce fruit every year, while in another region this tendency is less marked or not shown at all.

Outside the U.S.S.R., some research workers talk about the difficulty or impossibility of achieving annual fruit-bearing in the case of some apple varieties, while others recommend solving this problem only by breeding varieties capable of bearing fruit annually.

In the U.S.S.R., too, suggestions have been made that alternate fruit-bearing should be eliminated along the lines not only of altering the fruit-bearing habit of existing varieties, but also by breeding new, annually bearing apple varieties (R. R. Schreder, 1937, and others).

In Poland, it is considered that the reason for alternate fruit-bearing of fruit stocks is the cultivation of unsuitable varieties, severe winters, spring frosts and the low cultural level in the orchards (S. Sochek, 1957).

In the U.S.A., alternate fruit-bearing is strongly marked among the Baldwin, Wagener, York Imperial and Wealthy varieties, while McIntosh, Ben Davis, Rome Beauty and Twenty Fuchs have a strong tendency towards annual fruit-bearing (W. H. Chandler, 1957).

Below are data on a series of standard varieties which tend in various degrees to produce fruit annually. For Uzbekistan, the first group includes Napoleon and Yellow Bellefleur, the second—Sary Synap, Rosmarine blanche, Orleans Reinette, Snezhny Calville, and the third —Candille Synap.

In the Krasnodar Territory, Simirenko's Reinette, Reinette de Champagne, Winter Golden Pearmain and Rosmarine blanche belong to the first group of anually bearing varieties.

In the Crimea, the varieties of apple trees are distributed as follows: in the first group—Simirenko's and Orleans Reinettes, Napoleon, London Pippin, Winter Golden Pearmain; in the second—Reinette de Champagne, Sary Synap and Rosmarine blanche; in the third—Candille Synap.

In the central zone of the U.S.S.R., Pippin Shafranny and Slavyanka relate to the first group; the Antonovka Obyknovennaya, Anis Polosaty, Bellefleur-Kitaika, Borovinka and Streifling to the second; Grushevka Moskovskaya and Zolotaya Kitaika—to the third.

In Moldavia and the Ukraine, Snezhny Calville, Winter Golden Pearmain, London Pippin and Pippin Litovsky belong to the first group.

When drawing up measures for the care of orchards, special varietal features should be taken into account. The main ones are: the nature of the variety, i.e., the degree of ability or tendency for annual fruit-bearing and the time the trees begin to bear fruit, the beginning and length of the period of fruit-bud formation, the group to which the variety belongs as regards the character of the fruiting growths (whether fruit spurs of fruit brindilles predominate), the character of the fruit drop, length and amount of new growth, leaf surface of fruiting and vegetative growths, etc.

Physiological and Biochemical Conditions for the Formation of Fruit Buds

One of the major problems in understanding fruit plants has for long been that of fruit-bud formation, taken as a physiological and biochemical complex.

Ch. Darwin and Y. Sachs (1880, 1881, 1893) considered that the cause of the onset of fruit-bearing was the formation in plants, under the influence of light rays, of specific "flower-forming substances", which stimulate the growing points to form flower buds, i.e., cause the organism to bear fruit. It was found impossible to isolate these substances and for a time there was no further development of this hypothesis.

Somewhat later an accumulation of organic substances (H. Müller-Thurgau, 1893) and a definite concentration of sugar in the cell sap (O. Loew, 1905) was found to be of special importance for the start of flower-bud formation. F. Klebs (1903, 1913, 1918) suggested that an accumulation in the plant of organic substances and a concentration of sugar in the cell sap was the essential condition for the beginning of fruit-bearing. In this connection intensity of the light, i.e., synthesis of carbohydrates and presence of inorganic substances, particularly nitrogen, plays a positive role, and it is suggested that the chief factor in this process is the ratio of carbohydrates and nitrogen in the plant. If the accumulation of carbohydrates predominates, the flowering begins, but if nitrogenous substances predominate there will be only vigorous vegetative growth.

During his experiments F. Klebs succeeded in getting several examples of controlling the flowering and fruit-bearing of fruit trees.

On the basis of six years' observations of the growth, development and fruit bearing of fruit trees and of meteorological factors, A. Krasichkov (1914) established that the growth of shoots and formation of fruit buds directly depend on summer meteorological conditions. For example, fruit buds are most abundantly formed during years when the first half of the year, i.e., the period of intensified growth of the tree, is marked with ample moisture in the soil, while the second half of the year has more sunny days and the air and soil are drier. He suggested that the weak concentration of organic substances elaborated by the leaves in

the spring and summer guarantees better fruit-bud formation.

D. Azzi (1932) also found that rain in the first half of the summer guaranteed sufficient development of fruitlets and fruits and successful formation of fruit buds. The explanation for this is that the abundance of foliage formed provides a sufficiently large amount of nutritive substances to supply the fruits and to form fruit buds for the next harvest.

R. Zorauer (1893) and later L. Iost (1914) put forward the idea that the formation of fruit buds and the flowering of fruit plants can only come about after large quantities of reserve nutritive substances have been accumulated in the growing points, which is possible, as W. Poenicke (1905) also affirmed, in circumstances of deterioration or physical suppression of vegetative growth.

E. I. Kraus and K. A. Kraybil (1918), by regulating the content of sugars in tomatoes by varying the light intensity, and the content of nitrogenous compounds by introducing them in different doses, arrived at the conclusion that to ensure successful flowering in tomatoes it was essential for the concentration of sugars to be greater than that of nitrogenous compounds.

The hypothesis that the ratio of carbohydrates to nitrogen is a factor determining fruit-bud formation and fruit-bearing has long prevailed in horticulture.

However, as far back as 1920, H. D. Hooker, carrying out research with apple trees, had already reached the conclusion that in an "off" year, during the period when fruit buds were being formed for the following year they contained more starch than nitrogen. Hence, in his opinion, the ratio of starch to nitrogen is a better indication of the tendency of fruit trees to form fruit buds than the ratio of carbohydrates to nitrogen. Some scientists hold that an accumulation of large quantities of starch is not always accompanied by the formation of an abundance of fruit buds.

Apparently the formation of fruit buds is more closely linked with the tree's total leaf surface in relation to the amounts of growth of the wood and the number of fruitlets formed than with the accumulation of starch. It can also be said that the chemical processes in the tree are highly complicated, and therefore conclusions drawn only on the

basis of carbohydrate analyses can hardly be justified (W. H. Chandler, 1957).

The researches of several scientists (G. F. Potter and T. G. Phillips, 1930; Y. Asami and H. Ito, 1937) have shown that the necessary reserves of carbohydrates and nitrogen are far more important for the formation of fruit buds than the ratio of carbohydrates to nitrogen.

M. Z. Bielinska (1957) considers that the bearing of fruit trees is closely connected not so much with reserves of carbohydrates (e.g., starch), but with the direction taken by nitrogen transformations in their tissues.

G. F. Potter and T. G. Phillips (1930) found that fruit spurs which form fruit buds contain more potassium and phosphorus than sterile ones (spurs without fruits). The relation was established between the content of proteins and the formation of fruit buds. It appeared that the higher the nitrogen content in the branches, the greater was their tendency to form fruit buds.

A marked, positive correlation was established also between the dry weight, the amount of dry matter of the fruit spurs, and the formation of fruit buds on them. It follows that the longer, heavier and larger spurs are better for forming fruit buds than the others.

P. K. Ursulenko (1939) drew attention to a possible connection between fruit-bud formation and the content of protein nitrogen in the fruit structures. On the basis of the dependence of nitrogen metabolism on the presence of sugars in the new growth of plants (D. N. Pryanishnikov, 1895), in the leaves (K. Mothes, 1926) and in the entire adult plants (G. T. Nightingale, 1934), he concluded that where there is carbohydrate starvation, nitrogen does not change to organic forms but is stored in plants in ammoniacal and nitrate forms. As the mass of carbohydrates increases, the nitrogen changes into amides and amino-acids and then into protein compounds. The better the nitrogen metabolism in plants the more carbohydrates there are which are utilized in building up a skeleton of amino acids and in energy processes connected with the synthesis of nitrogen into protein compounds. By investigating different forms of nitrogen in plants with varying degrees of flowering, P. K. Ursulenko found that abundant flowering is accompanied by an excessive expenditure of carbohydrates, in consequence of which nitrogen synthesis

Table 14

does not proceed as far as the formation of proteins but remains at the level of amino acids, as seen in Table 14.

Content of Various Forms of Nitrogen in Fruiting Growths of Apple Trees Showing Different Degrees of Flowering

Degree of flowering	Time when samples were taken for analysis	In per cent of total nitrogen		
		protein	amine	ammoniacal
Heavy flowering	End of flowering	50.8	25.6	8.4
	Prior to physiological fruitlet drop	42.6	33.1	10.2
	Beginning of fruit-bud formation	46.2	40.8	4.6
Average flowering	ditto	60.2	24.8	3.9
		65.7	19.6	4.2
		70.1	12.1	2.2
Nonflowering	ditto	68.1	21.6	3.6
		75.6	15.2	2.2
		83.6	8.5	1.2

The shift in metabolism in the presence of a surplus of carbohydrates in the direction of increased protein synthesis provides conditions for the formation of fruit buds. For example, fruit buds were formed when the usual content of protein nitrogen on the fruiting branches of the Antonovka Obyknovennaya tree was 72 per cent of the total amount; with 55 per cent nitrogen, these buds were not formed, as shown in Table 15.

Table 15

Influence of Flowering Vigour on Nitrogen Metabolism in the Fruiting Growths of the Antonovka Obyknovennaya Apple Tree

Variant of the experiment	In per cent of total nitrogen			Per cent of fruit buds formed
	protein	amine	amide	
Branch with 20 per cent flowering vigour	72	19.2	3.0	22.1
Branch with 90 per cent flowering vigour	55	37.0	1.0	0.0

On both these branches there were 50 leaves per fruit. On the basis of the results of this experiment and others connected with harvest regulation, the author concluded that elimination of the habit of alternate bearing in apples requires a moderate number of fruit buds—not more than 30-40 per cent per tree.

A high protein content is closely connected with a sufficient accumulation of carbohydrates produced by the leaves. Protein synthesis increases only if there are approximately 50 to 75 leaves per fruit. In this case the fruit-bearing tree is in a position to form fruit buds, which exactly coincides with the protein content in the fruit spurs of 70-80 per cent of the total nitrogen.

P. K. Ursulenko (1939) considers that in an "off" year, when the apple tree has a surplus of carbohydrates, a large amount of protein nitrogen is accumulated. This situation leads to excessive formation of fruit buds, sometimes reaching almost 100 per cent, and this is not only unnecessary for the tree but deprives it of the possibility of forming new fruit buds in an "on" year.

Research in the Crimea by A. A. Basanko and V. V. Petrova (1939) led them to conclude that the best indication of the readiness of the adult apple tree to form fruit buds will be the total quantity of both nitrogen and carbohydrates, both in absolute amounts, and in the ratio between them.

Mass formation of fruit buds is connected with a high carbohydrate and low nitrogen content. For example, the amount of total nitrogen is approximately halved in an "off" year as compared with an "on" year.

Developing D. Krasichkov's idea (1914) of cell-sap concentration, I. A. Kolomiets (1961) found that the complexes of conditions necessary for fruit-bud formation and for growth and development of vegetative structures do not coincide. Most important are the moisture conditions and the concentration of nutritive substances entering the meristematic cells of the growing fruit formations.

Apple saplings in the orchard do not form fruit buds because concentration of nutritive substances is always low in them, owing to the small number of leaves. In bearing apple trees, fruit buds can be formed primarily on young fruit spurs, i.e., on the youngest branches, where the appropriate concentration of nutritive substances appears more

often and more rapidly than in the older fruiting wood spur systems. In alternately bearing apple trees, fruit buds may not be formed during a harvest year because of the low concentration of nutritive substances, but in trees having no harvest, this concentration is often high, and too many buds on the tree become fruit buds.

I. A. Kolomiets suggests that, knowing these specific features of the tree, specific measures can be devised to create the conditions necessary for fruit trees to begin producing fruit earlier and more abundantly.

G. I. Nilov made a study in the Crimea of the content in fruiting twigs on yielding and non-yielding apple trees not only of total and protein nitrogen, but also of organic phosphorus and potassium.

In both groups of apple trees (Simirenko's Reinette, Reinette de Champagne and Candille Synap) a high content of protein nitrogen (80-90 per cent) was found. But no fruit buds were formed on the yielding trees. Fruit buds were formed when there was an increase in the supply of organic phosphorus. Further, no connection was found between the formation of fruit buds and the level of the protein nitrogen content in the plant (V. V. Petrova-Grinenko, 1939).

In his experiments, V. S. Monastyrsky (1954) observed the formation of fruit buds with both a high (85.92 per cent) and relatively low (58.92 per cent) ratio of protein nitrogen to total nitrogen in the new growths of fruit spurs. In his experiments, fruit buds failed to be formed even with a very high content (up to 90 per cent) of protein nitrogen.

The hypotheses of P. K. Ursulenko (1939) and I. A. Kolomiets (1954, 1961) are undoubtedly of value, but they are not yet sufficient, since they deal only with the apple tree, although this is the largest fruit crop as regards area; besides they cover only a small part of the complicated biochemical changes in plants.

In 1928, scientists again returned to the hormone theory. F. V. Went (1928) explained that the growth of the root was due to the influence of a specific rootforming hormone-rhizokalin, while N. G. Kholodny (1935) ascribed the germination of seeds to the influence of the hormone blastanine, the physiological properties of which were identical to those of the hormone auxin.

M. Kh. Chailakhyan (1936), from studying the influence of the length of the light period on the formation of fruit buds, concluded that just as in growth processes the growth hormone acted as a regulator, so also in flowering processes the same role is played by a specific "flowering hormone". It follows that flowering in plants occurs as a result of the formation in the leaves and transmission to the growing point of an adequate amount of a flowering hormone.

Subsequent researches led him to the conclusion that changes in the ratio of sugars, nitrogenous compounds or auxins, and vitamins are not connected with the flowering of plants, but are due to the influence of an accumulated flower-forming hormone—florigen. The flowering of long-day plants can only be accelerated where there is an increase of sugars, and, in the case of short-day plants, of nitrogenous compounds.

Many facts indicate that the shape of plants, the development of their organs and fruit-bearing, can be partially regulated by hormones, synthesized in very small quantities compared with the content of starch, sugar and protein in the plant tissues (N. F. Childers, 1947).

Some research workers consider that thought should also be given to the possibility of the supply of flowering hormones becoming exhausted or of their inadequate formation during a fruit-bearing year (C. P. Harley *et al.*, 1942).

Later M. Kh. Chailakhyan (1954) became convinced that fruit-bud formation is the result of the joint activity of leaves, stem buds and roots and that "flowering hormones themselves, arising in definite conditions as metabolic products, in their turn influence the change in metabolism which precedes formative processes" (1958).

In 1955, F. Skoog put forward the suggestion that the transition to flowering is brought about by chemical substances which destroy the polarity of the progress of the growth-promoting substances. Thus, triiodobenzoic acid which accelerates the flowering of many plants, disturbs the polar translocation of auxins along the shoots.

In W. H. Chandler's opinion (1957), the most likely suggestion is that under conditions favourable to accumulation of starch in the tree, some kind of hormone which regulates fruit-bud formation may also be accumulated. This hormone can be an organic compound in which nitrogen

is possibly present. Convincing data were obtained by staff members of the U.S. Department of Agriculture in Florida indicating that some substance contained in the leaves of mango plants and capable of translocation both upwards and downwards along the phloem of a shoot, can bring about the formation of flowers in buds, if their cells are at the stage of dividing.

In W. H. Chandler's opinion, of all the available data the most serious working hypothesis about the origin of flowers in deciduous fruit trees is the following: cell-division can continue in the bud almost until the leaves closest to it reach their full size. In suitable conditions the leaves along the shoot or on adjacent shoots can form a hormone capable of inducing flowering in buds in which formation of apical meristem is still going on. If the formation of leaf initials has begun, e.g., in the bud of stone-fruit trees, or the period of complete dormancy has begun, the hormone may be found to be ineffective.

Some research workers consider that successful fruit-bud formation depends on the use of the nutritive substances stored in the tree during past years (C. P. Harley *et al.*, 1942), on the ratio between various branches, particularly young ones (V. M. Sergeyenko, 1939), on cultural practices and other causes, which are examined below.

Generally speaking, on the basis of the experimental data outlined above, it is possible to reduce the hypotheses and theories of the causes of fruit-bud formation to the following: the hormone theory, the theory of the ratios of separate elements of carbohydrates, nitrogenous and mineral compounds, including those of a reserve nature, the theory of the concentration of cell sap and of the proper nutrition (or of the entire orchard management) of plants.

Attempts to reduce the cause of the formation of fruit buds to some single factor or even several factors—the ratio of carbohydrates and nitrogen, the predominance of protein nitrogen, the supply of phosphorus, etc., are not convincing: each of these factors only partially characterizes the important and complicated process of fruit-bud formation in fruit-bearing plants. In our opinion, the cause of fruit-bud formation in apple trees should be sought in the presence not of any one compound, but in the sum total of nutritive substances in fruit plant, which evidently all operate together.

The researches cited above individually could not include the whole complex of the biochemical process which ensures the annual formation of fruit buds and fruit-bearing in the fruit plant. To a considerable extent these researches supplement one another and, in our opinion, do not contradict one another. Due to these researches a wealth of valuable material has been collected, but the phenomenon in question requires further study.

There must be a more complex investigation of the part played in fruit-bud formation not only by the aerial parts of the plant (to which all the above-mentioned works are devoted), but in no less measure by the root system, and also of their interconnected vital activities. Of great importance here is the root nutrition of plants, to which attention should be paid in further investigations of the causes of fruit-bud formation in fruit varieties, first and foremost in apple and pear trees.

Undoubtedly, the factors ensuring annual formation of fruit-buds are extremely varied and evidently they usually operate jointly. The basis of an annual yield is the correct and adequate nutrition (root and aerial) of the fruit-bearing plant, i.e., the timely supply to it of all the necessary nutritive substances and moisture. We have been convinced of this by the examples of annual fruit-bearing in orchards where cultural measures are carried out at the proper time.

Influence of Natural Conditions and Cultural Practices on the Habit of Alternate Bearing

Alternation of fruit-bearing in forest species, e.g., in conifers (cedars, pines and firs), as many research workers (G. F. Morozov, N. S. Nesterov and others) have found, depends largely on climatic conditions. Moreover, in the species indicated, alternation of fruit-bearing decreases more or less going from West to East, i.e., from less favourable to more favourable environmental conditions. The same is revealed in fruit plants.

The chief factors of the environment which induce fruit trees to produce high yields annually are light, temperature, moisture and nutrition. Control of these factors is largely in the hands of the fruit grower.

For example, a positive influence is exerted by the application of nitrogenous, phosphoric and potassium fer-

tilizers in early spring or autumn and also by the summer application of fertilizers as extra nutrition (N. A. Levashov *et al.*, 1939). Up to six or seven extra dressings, beginning from early spring, can guarantee moderate fruit-bud formation and equal annual fruit-bearing in apple trees (N. I. Smirnov, 1939).

Heavy fertilizing, as N. D. Spivakovsky's experiments (1940, 1949) showed, ensure abundant fruit-bud formation in apples, ammonium fertilizers stimulating vegetative growth and nitrate ones improving still more the conditions for fruit-bud formation. Consequently, it is important to use the required ratio in applying fertilizers.

Experiments of N. A. Mezhuyev and P. E. Kravchenko (1941) showed that adequate irrigation (70-75 per cent of the full moisture capacity of the plot) and use of fertilizers ensure good growth of shoots, successful formation of fruit buds and annual fruit-bearing continuously during five years without any harvest regulation.

S. F. Vyunov (1954) obtained fruit-bud formation in young apple trees during their 3rd to 4th year by irrigation and three extra dressings during the early part of the growing season, while with the usual cultural practice trees of the same varieties only started to bear fruit when 5-7 years old. This experiment made it possible to conclude that young trees with strong vegetative growth are also capable of beginning to bear fruit if sufficient carbohydrates are built up in them not only for growth but also for fruit-bud formation.

Some research workers hold that the best fruit-bud formation takes place in apple trees where there is moderate soil moisture during 1-3 months of the critical period after flowering. Some apply this also to citrus trees and subtropical plants (e.g., olive and litchi). These phenomena are evidently connected with the cessation of vegetative growth, which is an important factor affecting fruit-bud formation.

An excessive lack of moisture in the soil after the flowering period in citrus trees and olives can later retard their passage from flowers to fruitlets and fruits and also hold them back in the form of fruitlets. It is fully possible that once formation of fruit buds has begun, their further differentiation demands an appropriate, but not excessive, supply of moisture.

Trees of the majority of varieties growing on shallow, poorly aerated soils and in climatic conditions less favourable for strong growth of new shoots and intensive photosynthesis, have a greater tendency towards periodicity than trees on deep, well-aerated soil (W. H. Chandler, 1957).

By introducing increased doses of mineral fertilizers raising the concentration of the soil solution from 0.1 to 0.15 moles in glasshouse experiments I. A. Kolomiets (1959) caused fruit buds to be formed on one-year-old apple saplings (Borovinka, Bellefleur-Kitaika, Papirovka, Antonovka, Simirenko's Reinette, etc.). Consequently, the concentration of nutritive substances plays a positive role.

According to the data of Bulgarian research workers (V. Velkov *et al.*, 1957) it was found that with good management it is relatively simple to maintain annual fruit-bearing in varieties with a late or more lengthy period of differentiation of fruit buds.

Old and young fruit spurs grow very quickly at the beginning of the growing season chiefly at the expense of reserve substances. Therefore, applying nitrogenous fertilizers after harvest at the end of September and ensuring a good water supply for fruit trees in the autumn promotes the accumulation of large quantities of moisture and organic substances, which guarantees the best possible conditions for them during the winter and the best growth and development of leaves, new shoots, flowers and rootlets in the spring of the following year.

P. K. Ursulenko (1956) considers that additional foliar application of nutrients for apple trees with fruits should be given before the "June drop" phase so as to build up favourable nutritive conditions which promote the differentiation of fruit buds. At this time, too, sufficiently high moisture in the soil must be ensured. One month or six weeks after the first foliar application of nutrients in an irrigated orchard, a second application is given of phosphorus-potassium fertilizers which raise the frost-resistance of fruit trees. During the dormancy period in the growing points active division of the meristematic tissue ceases. In the second half of the summer and early autumn favourable nutritive conditions and a normal moisture regime must be established in order to ensure optimum activity of the foliage and an accumulation of organic substances which build up frost-resistance in fruit plants.

The application of nitrogenous fertilizers at the beginning of the growing season ensures the best development of new shoots and leaves, and also the formation of a moderate number of fruit buds for the following year's harvest. Application of extra nitrogenous dressings after the July fruit drop not only has a positive effect for annually fruit-bearing varieties, but can also help to get better fruit-bud formation on varieties which tend to bear fruit in alternate years.

Many fruit growers recommend pruning tree and soft fruits as a radical method for obtaining annual fruit-bearing. One of the first fruit growers to try to interrupt fruit-bearing by pruning was R. K. Roberts (1920). M. Telezhinsky (1938) successfully used heavy pruning on wood several years old. He found that such pruning reduces the amount of old fruiting wood and the resulting new growth increases the amount of young wood which can decrease the formation of too many fruit buds to the necessary extent.

Recently M. I. Vivian (1956) put forward a hypothesis explaining the effect of branch-pruning during dormancy on the growth of young trees next year. In his opinion, such pruning makes it possible to considerably restore in the fruit tree the necessary proportion between meristematic and nonmeristematic tissues.

Good results in eliminating atlernate fruit-bearing of apples in Czechoslovakia were obtained from summer dressings and fertilizing, watering, renewal pruning and selection of seedling stock (A. Dvorak, 1959).

The reaction of fruit-bearing trees to pruning varies, depending on their vigour and the ratio of vegetative to reproductive growth and also (according to A. B. Beakbane and E. C. Thompson) on the distribution of living tissues in the root system. On the other hand, there are many examples where the reaction to different degrees of pruning varied depending on the total reserve nutritive substances necessary for regeneration of tissues.

The tendency towards alternate fruit-bearing is somewhat reduced by rather hard pruning during the dormancy period. Such pruning usually reduces the number of fruit buds formed and subsequently flowering and fruit-formation—the consumers of organic substances—to a greater extent than the area of the remaining leaf surface which synthesizes various organic substances. However, winter pruning can be sufficiently heavy leading to a considerable

lowering of the yield in relation to the leaf surface, and thus providing regular fruit-bearing, but can also lower the yield so much as to become economically unprofitable (W. H. Chandler, 1957).

Experiments have shown that before an "on" year it is necessary to reduce the pruning of apple trees, and prior to a year with a smaller yield—to increase it considerably. The removal of twigs with a large number of wood buds before an "on" year leads to an increase in the percentage of fruit buds, but abundant flowering together with a small number of leaves leads to the exhaustion of the tree and consequently to alternate fruit-bearing (V. Velkov, 1955).

Pruning strongly activates and alters biochemical processes in fruit-bearing plants. Thus, according to Y. D. Zelinskaya's investigations (1949) one effect of pruning is an increase in sugar content in the new shoots on apple-tree branches at the beginning of the growing season, which causes increased hydrolysis of starch in the roots of these trees during the same growing season. In the second half of the summer and in the autumn more starch is accumulated in both the branches and roots of such trees than in those of unpruned trees.

According to G. K. Karpov's investigations (1958), pruning increases the moisture content particularly in branches and also in spurs at the phase of fruit-bud differentiation as compared to feebly developed spurs. At the phase of intensified growth and differentiation of fruit buds on nonfruit bearing branches, pruning increases the content of protein nitrogen which, in G. K. Karpov's opinion, facilitates the formation of fruit buds.

One of the leading Rumanian orchards that have eliminated alternate bearing of plum trees is that of the Istritsa experimental station, Mizil district, Ploesti Region. At the station, the 30-hectare plum orchard has been producing an annual harvest since 1946. This was achieved by a general improvement in orchard care. Besides fertilizers and pest and disease control, attention was given to shaping and pruning the crowns. The tree is shaped like a vase with 4-5 branches in the form of a stepped pyramid with an axis but with the upper steps not carefully carried out. The average number of lateral scaffold branches in each crown is 55-60 instead of the 111 in the control trees (not pruned), and the distance between these branches is 35-80 cm as

against 15-20 cm in the control trees (N. Constantinescu, 1957).

With identical care of trees of the same age and variety, some of them bear fruit each year, others having partially regular bearing (2-3 years consecutively), and yet others bearing alternately, i.e., trees also display their own individual characteristics. V. M. Sergeyenko gives several examples of switching fruit trees to a different type of fruit-bearing by means of improved care. For example, on the experimental plot of the Crimean fruit station before 1946, 310 trees produced fruit every year. With improved care, by 1949, 2,051 (or 76.5 per cent) trees began to produce fruit every year.

In the Chkalov State Farm (in the Alma River valley) the reason why the Reinette de Champagne apple variety which has only a moderate tendency towards annual fruit-bearing nevertheless bears fruit annually was the high cultural level: alternation of bare fallow with lucerne crops, furrow irrigation and sprinkler irrigation, regular fertilizing and extra dressings of nitrogen, timely pest and disease control.

In our experiment in the Moscow Region (1953) when, during the entire growing season, optimum conditions were created for the growth of the tree (by irrigation; moreover, the year was a damp one), the roots grew relatively evenly throughout the entire season (in spring, summer and autumn, i.e., 8-9 months, and not 4-5 months). In our opinion, the longer joint work of leaves and active roots during the year can ensure that the tree will form fruit buds in the current "on" year.

In recent years, thanks to increased fertilizing of fruit crops and improved methods of pest and disease control in the U.S.S.R., there are increasing numbers of examples of higher yields and of the elimination of alternate fruit-bearing in the orchards, including apple orchards.

The following harvests were gathered since 1957 in the Lenin State Farm near Moscow: 6.2, 9.5, 7.5, 11.9 and 12 tons per hectare (in 1961).

The result of applying an improvement scheme in the orchard of the Michurin Fruit-Growing Institute was that the yield of the Pippin Shafranny apple variety was: 28 tons per hectare in 1949; 39 in 1950; 15.8 in 1951; 29.4 in 1952; 36.2 in 1953 and 37.5 tons per hectare in 1954. This is not

only an annual harvest, but also a high one and comparatively even year by year.

Regular and even harvests can be obtained as a result of "on" and "off" years not coinciding on different plots in the orchard or in different varieties and also, apparently, of the capacity of certain varieties, given improved nutrition, to go over to annual fruit-bearing.

A calculation of apple tree yields in several Ukrainian state farms carried out by A. M. Ostroukhov (1953) showed that some of the trees of many varieties are capable of bearing fruit annually. Thus in the Oslamovo State Farm, Khmelnitsky Region, among the plantings of 17-year old apple trees on one plot where the level of orchard management was relatively higher than on the other ones, almost all the trees of the main varieties (Boiken, Snezhny Calville, Winter Golden Pearmain and others) grafted on *M. Sylvestries* gave a high yield every year.

In addition, artificial thinning out of some of the flowers, i.e., reducing their numbers by sprinkling with growth promoting and nutritive substances has an extremely beneficial effect. The varieties which particularly tend to bear fruit annually, sometimes in a particular year as a result of an excessive flowering, are found to be unable to form the necessary number of fruit buds for next year. Reducing the amount of flowers in such a case ensures such variety with quantitatively even annual fruit bearing. Thinning out of surplus flowers on fruit trees of any variety improves the general state of the trees and increases the size and commercial quality of the fruits.

Excessive flowering leads to a tremendous number of flowers and fruitlets dropping off. This means that the fruit trees lose a considerable amount of nutritive substances which are extremely necessary for the plants' growth and for feeding the remaining fruitlets.

Considerable work was done, particularly in 1928-1939, both in the U.S.S.R. (P. G. Schitt, N. G. Zhuchkov, D. M. Shimanova, A. K. Priimak, and others) and abroad (I. R. Magness, T. Swarbrick, G. F. Potter and others) on manual regulation (reducing the amount) of flowers, fruitlets and fruits. This method was found to be very effective in improving growth, fruit-bearing and the quality of the fruits and, sometimes, provided it is carried out early, in getting some varieties to go over to annual fruit-

bearing. But this method was abandoned because of its high cost. In this connection the U.S.S.R. and other countries almost simultaneously began to work on regulating the amount of flowers and fruitlets chemically (V. R. Gardner *et al.*, 1939; I. F. Miroshnichenko and L. V. Bolton, 1939). A little later the chemical thinning of flowers and fruitlets began on a large scale in the U.S.A. and Western Europe (F. W. Hoffman *et al.*, 1947; L. C. Luckwill, 1948; R. Fritzche, 1950).

Experiments by I. I. Gunar and M. I. Kalinkevich (1961) over the last 5 years have shown that the best results in thinning are achieved when apple trees are sprinkled on the 2nd and 3rd day of mass flowering, when the first (central), usually the strongest, flowers are already fertilized and solutions of dinitro-compounds at a concentration of 0.06 per cent have no effect on them. Each tree is given about 30 litres of a solution of DNP (ammonium dinitrophenolate) or DNC (ammonium dinitroorthocresolate). A solution of these compounds used at this time kills the anthers and stigmas of lateral, weaker flowers, and because of this the harvests are formed in the central flowers.

The early removal of flowers by chemical means or by hand provides the remaining fruitlets with the best nutritive conditions. Calculated per hectare the average addition to the harvest of the Candille Synap variety was 7 tons, the Reinette de Champagne—1.3 tons, the Sary Synap—3.8 tons and the Antonovka Obyknovennaya—4.1 tons per hectare.

Positive results were obtained both in the U.S.S.R. and other countries by spraying with soda, DNOC and naphthylacetic acid. As many as 70 preparations were tried out. Experiments demonstrated a possibility of practical application of sprayings for thinning out flowers and fruitlets. But sometimes sprayings of this kind were accompanied by adverse effects in the form of leaf damage, subsequent destruction of the seed endosperm, and also by marked difference in the reaction of individual trees and branches to spraying, etc.

Fluctuations have been observed in response to spraying with chemical preparations, depending on the variety, age, vigour and individual character of the plant, as well as on environmental conditions and other factors. In the opinion of F. Kobel (1954) a serious shortcoming to which

insufficient attention is given, is the fact that dinitrocreosol compounds are very poisonous to honey-bees. The advantage of the alpha-naphthylacetic acid over dinitrocreosol preparations is that it is not poisonous to man, animals and, particularly, bees in the form of diluted solutions. In addition the effect of solutions of alpha-naphthylacetic acid on foliage is also minimal. Consequently, investigations should definitely be continued in this direction.

Heavy fruit drop prior to harvesting can be observed in orchards. This results in a smaller harvest. The causes of this fruit drop may be intensified flowering, insufficient fertilization and seed-formation, and also unsatisfactory nutrition.

When the fruit passes from growth to ripening, a change takes place in the nature of the conversion of substances: processes of synthesis become weaker and those of breakdown stronger. This leads to the formation of the cork abscission layer (inter-cellular) between the fruit and the fruit-stalk, in consequence of which the fruit breaks away and falls to the ground. In this phenomenon, the fact that the fruit becomes deficient in auxins—substances secreted by seeds while they are growing—plays a substantial role. By the time the fruit is ripe, the reserves of auxin in the cells have become heavily reduced, the abscission layer begins to appear and the fruits may drop prematurely.

In the past 15 years successful work has begun on working out methods of retaining fruits until they are picked by spraying trees with growth stimulators which improve metabolism in the fruit-stalks, retard the formation of the abscission layer and prevent fruit drop before harvest time. This method evidently holds good prospects but more extensive experiments are required.

Many authors stress the large differences in the effect itself and its duration caused by the same preparations and concentrations, depending on the different species and varieties of fruit crops as well as the meteorological conditions.

Some research workers have found that after applying certain chemical preparations and growth stimulators the fruits ripen early, keep on the tree perfectly well and sometimes hold so fast that when gathered the fruit spurs get broken. When working out cultural methods for obtaining annual harvests, fruit growers should know, and be able

to control, the rhythm of the vital activities of the aerial and root systems of fruit-bearing plants. By means of orchard management practices (nutrition, pruning, foliar dressings), the fruit grower can create conditions for moderate flowering, good annual growth, formation of a large number of leaves and their increased working capacity.

Soviet research workers and fruit growers, by improving the care of their orchards, have come to realize that trees of different varieties, including "capricious" ones, can be switched over to annual fruit-bearing. But varieties differ in the nature of their fruit-bearing; some produce fruit successfully every year under good natural conditions and with adequate care, others require additional measures of soil management and care of the tree, others again show marked periodicity, the causes of which have not yet been studied, and measures to overcome it have not yet been found.

In can be said that the entire complex of orchard management plays an extremely important role in establishing annual harvests of fruit and berry crops. This complex has to ensure for every species and plants of varying ages annual growth increments of sufficient length with healthy and abundant foliage, the presence on the tree of fruiting growths of all ages but particularly young ones (brindilles, dards, fruit spurs), a more prolonged growth of active roots during the growing season, also most certainly in the autumn and late autumn period.

In short, a differentiated approach should be used both with respect to the soil and to climatic conditions of the future orchard and to the species, varieties, seedling stocks and age of trees. In that event it will be possible to get high yields of fruit and berry crops every year.

CHAPTER NINE

•

RESEARCH WORK WITH FRUIT PLANTS

History of Research Work

In pre-revolutionary Russia, by the end of the 18th and beginning of the 19th centuries there had already arisen, out of the requirements of production, the idea of the need to experiment with agricultural plants. The St. Petersburg Volunteer Economic Society was founded in 1765 and the Moscow Agricultural Society in 1818. These societies succeeded in uniting the most active agriculturists of the day. They held conferences and published magazines and newspapers providing much useful information to agriculturists.

Gradually there arose the idea of passing from individual, casual experiments to special experimental fields and stations for systematic investigations into agricultural plants. This idea was ardently supported by D. I. Mendeleyev (1834-1903), K. A. Timiryazev (1843-1920) and other scientists. The following experimental fields were set up: the Poltava field in 1884, that of Kherson in 1891 and of Odessa in 1896. Later, agricultural experimental stations were opened, e.g., the Shatilovskaya and Kostychevskaya. A. A. Izmailsky, a prominent agronomist of the second half of the 19th century, wrote: "The time has come to realize that in order to solve problems on agricultural technique, properly organized investigations are essential, as well as practical experiments based of these investigations. These should be carried out at experimental fields and stations specially adapted for the purpose".

In the field of fruit growing in pre-revolutionary Russia investigations were carried out on a small scale in several agricultural higher educational institutions, agricultural schools and experimental establishments. Among the earliest (80-100 years old) are the Bureau of Applied Botany

in St. Petersburg (now Leningrad); the Petrovskaya (now Timiryazev) Agricultural Academy, and the Sukhumi, Sochi and Tashkent agricultural experimental stations. In 1913, experimental stations were opened in Yekaterinoslav (now Dniepropetrovsk), Simferopol (known as the Salgirskaya Station) and Tula.

Botanical gardens, founded in Moscow in 1706 under Peter the First, in Yekaterinoslav in 1806, in Yalta (now the Nikitsky Botanical Gardens) in 1812, and later in Odessa, Voronezh and Kishinev also played a positive role in the development of horticulture. Moreover, after 1838 horticultural magazines started appearing in Russia.

All these experimental institutions, botanical gardens and magazines were established owing to the persistence of prominent individual horticulturists.

Among such people was A. G. Bolotov (1738-1833), who in 1797-1801 issued a handsome work in 10 volumes in which he described 600 native varieties of apples and pears. He recommended using natural intravarietal hybridization with subsequent selection and training of the seedlings to obtain new varieties; he showed the biological importance of cross-pollination, and the role played by honey bees. Bolotov recommended taking cuttings from the most fruitful upper branches of trees, etc. R. I. Shreder was chief gardener, dendrologist and instructor of the Petrovskaya (now Timiryazev) Agricultural Academy. In 1877 he published a valuable book entitled: **The Russian Vegetable Garden, Nursery and Orchard**, which was published in several editions and was long used by all horticulturists.

Among the prominent orchardists of the last century mention should be made of M. V. Rytov, who published most useful textbooks on fruit- and vegetable-growing, N. I. Kichunov, who published several textbooks and articles on fruit growing, landscape gardening and floriculture, and L. P. Simirenko, who wrote the classic "Crimean Commercial Fruit Growing" (1913).

Many prominent research workers in the field of fruit growing who had done a great deal in the pre-revolutionary period continued to work successfully in the Soviet times. Among them were I. V. Michurin, V. V. Pashkevich and I. L. Grebnitsky, whose works are used by scientists and fruit growers to this day.

The Soviet period has seen the vigorous development of socialist agriculture (in collective and state farms), which has stimulated extensive and intensive research by agricultural establishments and contributed to their close interrelations with practical fruit growing. The new principle of zonal location of scientific establishments throughout the country was put forward which led to the establishment of (1) state experimental stations gradually organized in all regions, territories and republics; (2) zonal research institutes throughout the large natural zones of the U.S.S.R.; (3) branch research and experimental stations for the most important crops and sections of agriculture, and (4) the Lenin All-Union Academy of Agricultural Sciences (VASKhNIL).

The Academy was founded on June 25, 1929. Its main tasks are: the fullest development of the plant- and animal-breeding resources of the U.S.S.R., scientific co-ordination and working out of vital agricultural problems, scientific generalization of the results of the work of the experimental institutions and leading workers in agriculture, ascertainment and utilization of the achievements of world science and production. All higher agricultural educational institutions are subordinate to the Academy as regards guidance and coordination of scientific work.

From the earliest years of the Soviet period, attention was also directed to developing research in fruit growing. On November 18, 1918, the government took over I. V. Michurin's nursery as a research institute and appointed I. V. Michurin its director; in 1931, in the town of Kozlov (now Michurinsk), research and educational institutes were opened and the nursery was converted into the Central Genetical Laboratory (C.G.L.). In 1920, for the first time in the U.S.S.R., the Department of Fruit Growing was founded at the Timiryazev Agricultural Academy in Moscow, of which P. G. Schitt was the head for 30 years.

During the Soviet period, a network of fruit growing research institutions has developed. The following exist today:

I) **Branch Institutes:** The All-Union Research Institute of Subtropical Plants and Tea (Makharadze, Georgian S.S.R.).

II) **Zonal Institutes:** 1) The Azerbaijan Research Institute of Horticulture, Viticulture and Subtropical Plants (Baku).

2) The Armenian Research Institute of Viticulture, Wine Making and Fruit Growing (Yerevan).

3) The Byelorussian Research Institute of Fruit, Vegetable and Potato Growing (Minsk).

4) The Georgian Research Institute of Horticulture, Viticulture and Wine Making (Tbilisi).

5) The Zonal Research Institute of Horticulture and Viticulture (Hojent, Tajik S.S.R.).

6) The Kazakh Research Institute of Fruit Growing and Viticulture (Alma-Ata).

7) The Moldavian Research Institute of Horticulture, Viticulture and Wine Making (Kishinev).

8) The Zonal Research Institute of Horticulture of the Non-Chernozem Belt (Moscow).

9) The Research Institute of Horticulture, Viticulture and Wine Making (Uzbek S.S.R.).

10) The Research Institute of Horticulture.

11) The North Caucasian Zonal Research Institute of Horticulture and Viticulture (Krasnodar).

12) The Ukrainian Research Institute of Horticulture (Kiev).

There are also experimental institutions which are devoted to fruit-growing problems, e.g.: 1) The All-Union Research Institute of Plant Industry (V.I.R., Leningrad); 2) The Nikitsky State Botanical Gardens (Yalta), and 3) The I. V. Michurin Central Genetical Laboratory (Michurinsk).

The sixteen experimental institutions mentioned above control 43 zonal experimental stations and 45 sub-stations situated in all fruit-growing zones from the Arctic to the subtropical regions of the U.S.S.R.

To complete the picture it should be added that there are other establishments devoted solely to viticulture and wine making: (1) the All-Union Research Institute of Viticulture and Wine Making "Magarach" (Yalta), (2) the Research Institute of Viticulture and Wine Making (Novocherkassk), and (3) the Ukrainian Research Institute of Viticulture and Wine Making (Odessa). They have four experimental stations.

Some republics, territories and regions have no fruit-growing research institutes, though there are agricultural research institutes which have departments of fruit growing. Such departments exist in Bashkiria, Daghestan,

Kazakhstan, Kirghizia, Latvia, Lithuania, Turkmenia, Estonia, Yakutia, and also in the Russian Federation; at the Agriculture and Afforestation Research Institute in Volgograd and at the Far Eastern Institute in Khabarovsk; in Rostov on Don, in Krasnoyarsk, at the Dokuchayev Central Chernozem Institute in the Voronezh Region, in the Kirov Region and at the Siberian Research Institute in the Omsk Region—totalling in all 16 institutes.

There are in addition 265 varietal experimental farms all over the country which carry out research in studying and evaluating varieties originated by Soviet breeders or introduced from foreign countries.

During the Soviet period the number of agricultural academies and institutes has increased several-fold. At present there are such institutions fifteen of them have fruit and vegetable faculties and fifty have fruit-growing departments and/or courses.

It should be borne in mind that research work on problems related to fruit growing is also conducted in many other research institutions, e.g., the institutes of genetics and selection, plant physiology, biophysics, soil science and other institutes of the U.S.S.R. Academy of Sciences, as well as in the institutes of agricultural economics and farm management, mechanization, land reclamation, plant protection.

Departments and Laboratories of the Institutes and Experimental Stations

The number of departments and staff workers in the research institutes depends on the size of the zone served and the area under tree and soft fruits. Institutes have as many as 120 and even more, and experimental stations 30 or more research workers, staff assistants and laboratory workers each.

Research institutes, such as the Nonchernozem Research Institute in the Moscow Region, have the following departments: 1) promotion and application of advanced experience of collective and state farms; 2) economics; 3) orchard management; 4) breeding and varietal study; 5) agrochemistry and soil; 6) mechanization; 7) plant physiology; 8) storing and processing; 9) plant protection; 10) ornamental gardening and floriculture, and 11) scientific library.

The fruit-growing experimental stations have the following departments: 1) breeding, 2) orchard management, 3) mechanization, 4) economics, 5) plant protection, 6) ornamental gardening, and 7) agrochemistry.

•

Research Problems and Objectives

During the Soviet period, many problems of fruit growing have been studied and the results applied but there are many more problems which need to be studied. The U.S.S.R. has an overall plan for several years of research work in agriculture and fruit growing. This plan contains one major problem of *increased production of fruits and berries*, which comprises several very important objectives put forward for the Republican and zonal fruit-growing research institutes, in fruit-growing departments of Republican and zonal agricultural research institutes, at experimental zonal fruit-growing stations and at departments of fruit growing at agricultural educational institutions.

The plan presented below was drawn up on the basis of the problems and objectives contained in the plan of the Lenin All-Union Academy of Agricultural Sciences for major research in agriculture during the coming years, and also in the plans for horticultural research of Republican and zonal research establishments.

The aim of this plan is to secure the correct distribution of research topics for the given problem among the research establishments throughout the country.

Work on the problem is proceeding under the general guidance of VASKhNIL; scientists to lead the work on the problem are chosen individually for all the Union Republics; the work is carried out jointly by the staff scientists of all the experimental stations and higher educational establishments concerned.

The plan envisages elaboration of the following important themes and problems for the years 1960-1975:

Theme 1. Distribution and specialization in fruit growing according to the zones and regions of the Union Republics.

Objectives: study of the natural and economic conditions of development, location of fruit-growing areas and of economic efficacy of fruit growing according to the zones and

regions of the republics. Selection of the most favourable zones and districts for the development of commercial fruit growing. Development, distribution and specialization of fruit growing according to zones, regions, territories and autonomous republics.

The research will result in determining and more clearly defining the districts where commercial fruit growing can be developed.

Theme 2. Demarcation of regions of fruit and berry crops according to species and varieties.

Objectives: productive-biological study of varieties of fruit and berry crops, their preliminary and commercial trials. Establishment of a rational proportion of species and varieties for new plantings.

The researches will result in the accurate plotting of the existing zonal distribution of fruit and berry crops according to the species and varieties.

Theme 3. Improvement of the assortment of fruit and berry crops.

Objectives: introduction, study and selection of the best varieties and clones, and the breeding of new high-yielding, high-quality, disease-resistant, winter-hardy and drought-resistant varieties of tree and soft fruits most adapted to definite ecological conditions.

As a result of the researches, the assortment of fruit and berry crops will be enriched by new varieties which would be more adapted to local conditions and economically more valuable.

Theme 4. Elaboration of the theoretical fundamentals of winter-hardiness of fruit crops.

Objectives: study of the physiological and biochemical nature of the morpho-physiological fundamentals of the winter-hardiness of fruit crops during intervarietal and remote crossing.

The anticipated results will be the discovery of the physiological and biochemical laws underlying the winter and spring damage to fruit crops as well as their winter-hardiness.

Soil management measures will be proposed for improving winter-hardiness of fruit crops, evaluation of initial forms in breeding fruit plants for winter-hardiness, and also laboratory methods of diagnosing fruit crops for winter-hardiness.

Theme 5. Elaborating a system of cultural measures for ensuring high annual yields of high-quality tree and soft fruits.

Objectives: study of the biological, biochemical and physiological laws of growth and fruit-bearing and of the specific features of nutrition and also, on the basis of the achievements in physics, chemistry, physiology, microbiology and related sciences, to elaborate or more clearly define and improve the existing cultural practices which ensure high and stable harvests of high-quality fruits and berries at lowest production costs; study and expansion of the cultivation of fruit-trees on dwarfing stocks.

As a result of the research work a more rational system of cultural measures will be elaborated and recommended to the industry and in a number of districts varietal orchard management to ensure high and stable yields, high-quality fruits and berries and lowest production costs will be recommended.

Theme 6. Raising the production and improving quality of planting material of fruit and berry crops.

Objectives: devising progressive methods of nursery management to ensure increased yield, improved quality and lower production costs of planting material; study and breeding of seedling stocks and winter-hardy vegetatively-propagated stocks.

Theme 7. Pest and disease control.

Objectives: working out improved and more effective means of controlling pests and diseases of tree and soft fruits. Testing and application in production of new toxic chemicals and methods of pest and disease control, e.g., by aircraft, which will ensure maximum preservation of high quality yield and prevent damage to orchards.

As a result of the researches, improved measures will be given for combating the principal pests and diseases of fruit and berry crops.

Theme 8. Mechanization of fruit-production processes.

Objectives: working out cultural requirements and design new machines for caring for the soil and plantings, spreading fertilizers, growing planting material, controlling pests and diseases and gathering the harvest. As a result of the researches, new and efficient machines will be produced to be employed in orchards, berry plantations and plant nurseries.

Theme 9. Working out of methods for storing fruits in collective- and state-farm conditions.

Objectives: devising methods for storing fruit at different stages of maturity in fruit warehouses capable of storing 100, 200, 300 or 500 tons, using up-to-date achievements in science and practice.

As a result of the researches carried out methods of preserving fruits in various fruit storage depots will be devised, their economically valuable qualities being preserved.

The plan outlined above covers the study of pome fruit, stone fruit, nut and berry crops. In addition, the VASKhNIL plan envisages the solution of another problem—increasing the production of tea, citrus fruits and other subtropical crops. This problem includes the theme: *Study of the biological and cultural requirements for producing high yields from citrus and other subtropical crops.*

Necessity of studying this theme: the cultivation of citrus fruits even in the most favourable conditions of the Soviet subtropics is complicated by the periodically repeating falls in temperature to a level that is critical for citrus crops, leading to heavy harvest losses and sometimes to the complete ruin of the plantations.

The task is to work out more effective means of protecting citrus crops from frosts and to ensure a more rational cultural management which will aid in obtaining high yields and greater winter-hardiness of citrus and other subtropical crops.

Work on the theme began in 1945 and is still under way.

Fulfilment of this theme: cultural practices have been worked out for the cultivation of citrus crops and optimum areas of nutrition, methods of cultivation in the open and under glass as well as methods of protection against frost have been developed. However, the methods proposed for protecting citrus plants from frosts are not sufficiently effective and are too expensive.

Cultural methods for the cultivation of feijoas, pomegranates, persimmons, figs and olives are so far inadequately worked out.

Anticipated results: methods for protecting citrus crops from frost, using various plastic materials and heating means, will be improved.

Work is being carried out by the All-Union Research Institute of Subtropical Plants and Tea in the Georgian S.S.R., the Azerbaijan Research Institute of Fruit Growing, Viticulture, Subtropical and Southern Fruit Plants.

•

Subjects and Specific Features of Root Study

It is our deep conviction that a thorough study not only of the aerial part but also of the root system of fruit and berry plants is also necessary. These two systems are closely connected throughout their whole life. Starting from this we give below certain questions or themes necessary to study.

Our country is today confronted with the task of establishing a scientifically substantiated system of land cultivation, including fruit growing. A profound and comprehensive study of the root system in close connection with the aerial portion of the plant, as well as with external conditions, will be of tremendous assistance not only in solving a number of theoretical problems of the physiology of fruit and berry crops, but also in elaborating a well-founded cultural system; it will also favour the further development of fruit growing in the Soviet Union.

In regard to the root system, there are as yet insufficient experimental data to regulate the vital activity of this important part of the plant organism. Nevertheless, the solution of a number of problems concerning the root system is already helping to provide a better basis for and definition of such cultural measures as: a) appraisal of new land areas under orchards and berry plantations; b) preparation of the soil prior to planting, and distribution of selected species and varieties according to the orchard area; c) timing and depth of soil cultivation, application of fertilizers, irrigation; d) establishment of stable, high, annual yields in fruit orchards and berry plantations.

Much that is new and of value in regard to the study of the root system of these crops has been obtained by research workers, particularly in the U.S.S.R., U.S.A., Britain and Japan, and in more recent years in other countries as well. But this is only a beginning to be followed by further research into the root systems of these crops. The immediate and urgent problems in studying root systems of fruit plants are, in our opinion, the following:

(1) **Elucidation of the objective laws governing the architectonics of the root systems of fruit plants in all the main zones of fruit growing in the country.** This includes a study of the specific features of the architectonics of the root systems in different soils, of trees with record harvests, of weakened trees and trees with dried-up crowns, under different systems of soil management, in orchards planted with one or several species (mutual influence of root systems), of root-pruning and regeneration and subsequent growth of these roots, etc.

This study will enable the fruit grower to give immediate assistance in improving the state of the fruit plant and its fruit-bearing.

(2) **Study of the dynamics (rhythm) of growth of active roots in existing orchards**, depending on species, variety, stock, soil and climatic conditions, age, yield capacity, state of foliage, and also of individual elements and of the entire cultural complex. This study should aim at working out methods to regulate growth and development of the aerial and root systems of the fruit plant.

(3) **Study of the architectonics and rhythm of growth and development of the root system of fruiting plants** in newly planted orchards, where the fruit grower from the outset could successfully direct growth and development of the root system as well as the growth and acceleration of fruit-bearing of plants by giving them appropriate conditions.

(4) **Study of the architectonics of the root system and crown of trees on the sites intended for new plantations.** This makes it possible to achieve the extremely important preliminary assessment of large tracts of land set aside for new fruit-tree plantations.

(5) **Study of root hairs and ascertainment of fruit species having mycorhiza on active roots;** study of the interrelation between mycorhiza and active roots, and study of the rhizosphere—the microbe world surrounding the active roots of the root system.

(6) **Breeding evaluation of hybrid plants chosen as future varieties.** From this point of view, great importance is attached to the vigour and structural character of the root system, i.e., the elements to which, unfortunately, not enough attention is paid, as a rule, in research on the breeding of fruit and berry crops.

Investigations should embrace simultaneously the aerial part of the plant, the soil complex and the cultural measures. As M.A. Keller (1935) stresses, "plants are particularly closely and intimately connected with their ever moving, ever changing, surrounding environment, which is constantly being changed by the plants themselves."

It is also important to investigate, or continue to investigate, the following problems: the biochemistry of the root system; development of new and dying off of old structures in the root system; the interconnection between the vital activity of the assimilating area of the leaves and of the absorbing roots; the mutual effect of root systems of varietywise homogenous and heterogenous plantings in orchards; the interconnection between the vital activity of absorbing roots in the autumn-winter period, the lignification of new shoots, the frost-hardiness of plants, and the desiccation of branches and new shoots during the winter period; the development of the root system of tree and soft fruits depending upon preliminary cultivation of the soil; the effect of pruning of the aerial and root system on root regeneration; the influence of growth stimulators on root-formation and root regeneration, etc.

By altering and improving the care of plants, including fruit-bearing plants, it is possible to obtain record harvests. But the fruit plant organism in general is extremely complicated and has been very little studied, particularly in regard to the root system. To achieve the necessary success in this direction, the research fruit grower should, first and foremost, know the correct methods of studying the root system of fruit-bearing plants.

The study of the root system, particularly its most complex questions, should be carried out in co-operation with workers investigating related branches of science (study of the soil, agrochemistry, physiology, etc.). This will simplify the task and guarantee trustworthy results. Joint investigations of the kind can provide the theoretical basis for controlling the growth of the root system of fruit plants and will serve as a more accurate theoretical basis for agro-technical measures in fruit growing.

Controlling the growth and development of the root and aerial systems of tree and soft fruits will favour the rapid elaboration and better theoretical substantiation of differentiated cultural practice for each fruit-growing zone,

and will help to achieve high annual yields in Soviet orchards. In addition, A. L. Kursanov (1954) stresses that further study of the root system in conjunction with deeper investigation into the problems of root nutrition will help to increase the general efficiency of agriculture.

Methods and Specific Features of Research

Three basic methods of experimental work are distinguished:

(1) field experiments carried out directly in fruit and berry plantations or in the nursery;

(2) laboratory experiments—the study of morphological, anatomical, physiological, chemical and other features of plants under laboratory conditions of an institution or experimental stations;

(3) vegetative experiments—study of the reaction of plants grown in water, sand or soil, under various environmental conditions.

Field experiments and investigations must be in the forefront as the most effective and comprehensive method of study, with laboratory and vegetative methods subordinated or included as accompanying.

Field experiments are the main type in the system of agronomic investigations since they are carried out under production conditions—in plantations of an experimental institution or higher educational establishment, as well as in collective- or statefarms, where they are systematically tested and improved.

For more successful scientific work on any of the questions contained in the plan of themes and problems for research, the above-indicated methods or method of on-the-spot experimental research should as a whole and without fail be accompanied by, or concluded with, the introduction of the obtained results into the industry.

The proper methodological approach, i.e., the one most useful for a particular purpose, is an effective and important weapon of the research worker. On it depends the success of any scientific work, as well as the accuracy convincingness of its results.

Before working on a theme the entire plan of research must be thought out and critically analyzed from the point of view of advanced agro-biological theory, the specific

biological features of the objects under study and of the environment being taken into consideration. It is important constantly to improve methods of research in order to acquire trustworthy experimental material and correctly interpret the results of experimental work.

In order to carry out successful research work, the experimenter should:

(a) study and systematically take account of the natural features of the district under investigation and the site where the experiment is carried out, particularly such factors as the soil and climatic conditions and the hydrothermal and atmospheric conditions, surrounding the experimental plants;

(b) correctly select the experimental plants;

(c) correctly apply the methods and continue studying the problem for a sufficiently long period;

(d) give an economic assessment of the different cultural methods which have been studied and recommended for use by the industry.

Tree and soft fruit crops, like other agricultural crops, are studied mainly by the field method.

Fruit-bearing crops in an experiment occupy concider-able areas as compared to herbaceous plants. For example, hundreds of herbaceous plants can be grown on a square metre, while one fruit tree alone occupies an area of 9 to 100 square metres. Furthermore, not infrequently dozens of trees have to be taken for an experiment in order to get a few treatments of the experiment and a few (2-4) replications. Added to this, since fruit trees are perennial, they have to be provided with individual care and assessment (measurement of the increase in the foliage area, etc.). Hence it is clear that differences in age and the individual variability of fruit-bearing plants, as well as the nonhomogeneous character of the soil over considerable areas under experimental plants, complicate the arrangement of the experiment and increase the possibility of erroneous conclusions.

Many years of research carried out by experimental fruit-growing establishments in the U.S.S.R. and other countries have led us to conclude that it is the duty of every research worker:

(a) to take more care in working out and substantiating the method of conducting experiment and the plan of

experimental work, to make a close study of the natural conditions of experimental plots, of the history of plantations and the state of growth and fruit-bearing capacity of each plant, to distribute correctly variants and replications of the experiment over the area;

(b) to carry out fully and at the proper time all necessary measurements and calculations, and to make physiological, anatomical, chemical and other analyses in order to establish the correct interconnection between the plant and the environment or estimate the effect of one or other cultural method, factor, etc.;

(c) to work properly on the data obtained; if necessary, statistical (biometrical) analysis should also be employed to make the results of the experiment more reliable;

(d) to give a true theoretical explanation of the data obtained and of the cultural measures recommended for the industry, and also assist in introducing them into the industry. The details of experimental work are available in the technical literature.

Example of Research

It is important to select a problem and specific themes for research which should be of immediate necessity for the actual district and place of study. The topic should contain the following main divisions:

(1) Importance of the topic; (2) Main questions for study; (3) Treatments and replications of the experiment; (4) Place where the experiment is to be conducted (soil and climatic conditions, history and state of plantations, etc.); (5) Elements of observations and calculations—general elements as regards the orchard (state of plantations and the cultural practice), the aerial portion of experimental trees, and the root system and soil complex; (6) Method of work—as regards the aerial system (phenology, growth rhythm of new shoots, stem, etc.), the root system (method of study), and the soil complex; (7) Plan for work over the whole research period year by year; (8) Approximate expenditure for the whole experimental period and detailed expenditure for the first year of the experiment.

We give here an example of the study of one question in an already existing orchard so that the research worker could take into account the basic conditions of the experi-

ment: (1) how far the fruit plantation is typical for the zone of activity of the experimental station where the research is carried out, i.e., how far the species and varieties of the trees and the soil conditions are typical; (2) the commercial character of the plantation and its state of health, i.e., the planting of the trees in rows, 3-4 standard varieties on accepted stocks per plot, normal provision of pollinating varieties and absence of noticeable gaps; (3) homogeneous management in the preceding 3-5 years (soil constitution, fertilizing, pruning, irrigation); and (4) provision of orchard-protective plantings.

Experimental planting requires preliminary study, namely, a soil survey should be carried out on the scale of 1 : 1,000, with a horizontal section through 20 cm and evaluation of the whole planting given with characteristics of the general state of each tree and account taken of its age, as well as the diameter of the trunk and size of the crown. The results obtained are entered on the plan. Together with the soil conditions they provide the basis for better selection of the size and shape of the experimental plots and the number of replications.

It is customary, depending on the purpose of the investigation and the conditions of the experimental sector, to use experimental plots of the following sizes: with fruit trees, from 10 to 20 plants; with berry bushes, from 20-40; with strawberries, 25-50 sq m; in a nursery, 60-120 plants; in a plot of seedlings, 25-50 sq m. Experiments should be repeated 2-4 times or more depending on the uniformity of the plantings and soil conditions. In most experiments a single row of trees (buffers) between the plots, on all four sides, must be provided, so that the care given to trees of one treatment of the experiment will not affect the trees of another treatment. In some of the more profound investigations (biochemical, physiological) smaller-sized plots are used with fewer plants, sometimes even with only one tree—the "tree-plot" method.

During the experiment the root system usually has to be studied at the same time. For example, when conducting investigations on soil management in the orchard, it is important to know the size and location of the root system which involves the "skeleton" and "cross section" method. When studying the growth rhythm of new shoots, it is important to study the mutually related growth rhythm

of the root system, which is done by the "free monolith" method (V. A. Kolesnikov, 1962).

Prior to the experiment a careful study is made of the plantation and the surrounding conditions, and then typical areas (plots), model trees and control branches are selected for more careful calculations of their vital activity. Account is systematically taken of the sizes of the crown and growth of the trunk (annually in the autumn), and also of the size and location of the root system in the soil, the main phases of the plants' development, new shoots (2-3 times a month), useful fruitlets and fruit drop, the quality of the yield in relation to the standard, the degree of maturation of new shoots and of front damage to fruit buds, new shoots and branches.

Each investigation continues for 2-5 or more years depending on the purpose of the investigation and nature of the experiment.

•

LITERATURE CITED

Asami, Y., and Ito, H. Studies on the Chemical Composition of Plants Associated with Flower Bud Formation. **J. Hort. Ass. Jap.,** 8, 337 (1937).

Basanko, A. A., and Petrova-Grinenko, V. V. Biochemistry of Apple Spur Tissues in Relation to Fruitfulness (in Russian). **Trud. Krym Plod. St.,** 2, 133-176 (1939).

Batjer, L. P., *et al.* Nitrogen Intake of Dormant Apple Trees at Low Temperature. **Proc. Amer. Soc. Hort. Sci.,** 42, 69-73 (1943).

Beakbane, A. B., and Thompson, E. C. Anatomical Studies of Stems and Roots of Hardy Fruit Trees. IV. The Root Structure of Some New Clonal Apple Rootstocks Budded with Cox's Orange Pippin. **J. Pom. a. Hort. Sci.,** 23, 206-211 (1947).

Bielinska, M. Studies on Nitrogen and Carbohydrates Content in the Leaves and Shoots of Biennial Bearing Apple Trees. **The Inst. of Pomology Skierniewice-Poland,** 2 (1957).

Bielinska, M., and Wlodek, L. Phosphorus, Potassium and Calcium Content of Leaves and Shoots of Biennial Bearing Apple Trees. **The Inst. of Pomology Skierniewice-Poland,** 3 (1958).

Belavin, Y. A. Phosphorus Supply From the Lateral Root to the Branches in a Grafted Apple Tree and in an Apple Tree Growing on Its Own Root. (in Russian). **Akad. Nauk SSSR Dok.,** 108 (1956).

Bini, G., and Chrischi, P. Some Observations on the Effect of Roots of Peach and Pear on Other Roots of the Same Species. **Riv. Ortofloro fruttic. Ital.,** 45, 945-952 (1961).

Blake, M. A. The Root System in the Foundation of the Apple Orchard. **Trans. of the Peninsula Hort. Soc.,** 22 (1933).

Bobrinsky, A. A. On the Flowering of Plants and Root Growth (in Russian). **Moskovsky Universitet** (1852).

Bunyatov, J. M. Influence of Microelements on the Yield of Fruit Plants (in Russian). **Ucheb. Zapis. Azerbaidjan. Univ., ser. Biol. Nauk,** 2 (1961).

Cerletti, P. Biochemical Aspects of Grafting and Incompatibility in Plants. **Ricerci scient.,** 30 (7), 921-954 (1960).

Chailakhyan, M. Kh. Gormonal Theory of the Development (in Russian). **Izd. Akad. Nauk SSSR** (1936).

Chailakhyan, M. Kh. Physiological Nature of Start of Flowering in Plants (in Russian). **Zhurn. obsh. biol.**, 15, 4 (1954).

Chailakhyan, M. Kh. Principal Regularities of Ontogenesis of Higher Plants (in Russian). **Akad. Nauk SSSR** (1958).

Chandler, W. H. Deciduous Orchards. London, 452 p. (1957).

Chefranov, A. P. Ground Water Levels in Crimean Orchard Soils and Their Influence Upon the Apple Root Systems (in Russian). **Trud. Krym. Plod. St.**, 11, 177-200 (1939).

Childers, N. F., and White, D. G. Influence of Submersion of the Roots on Transpiration, Apparent Photosynthesis, and Respiration of Young Apple Trees. **Plant Physiol.**, 17 (1949).

Childers, N. F. Fruit Science, 630 p. (1947).

Cholodny, N. G. Phytohormones (in Russian). **Izd. Akad. Nauk Ukr. SSR**, Kiev (1939).

Cossman, K. F. Citrus Roots: Their Anatomy, Osmotic Pressure and Periodicity of Growth. **Palestine Journ. of Botany**, Tell-Aviv, 3, 1 (1940).

Coutanceau, M. Fruit Trees. Paris, 575 p. (1962).

Curtis, J. T. The Relation of Specificity of Orchard Mycorrhizal Fungi to the Problems of Symbiosis. **Amer. Journ. Bot.**, 26 (1938).

Dadikin, V. P. Peculiarities of the Behaviour of Plants on Cold Soils (in Russian). **Izd. Akad. Nauk SSSR**, 277 p. (1952).

Davidson, O. W., and Shive, J. W. The Influence of the Hydrogenion Concentration of the Culture Solution upon the Absorption and Assimilation of Nitrate and Ammonium Nitrogen by Peach Trees Grown in Sandculture. **Soil Sci.**, 37, 357-386 (1934).

Davis, L. D. Flowering and Alternate Bearing. **Proc. Amer. Soc. Hort. Sci.**, 70 (1957).

Dominik, T. A., Jagodzinski, S. Researches on Mycorrhiza of some Fruit-Trees in Kornic-Gardens, 48-73 (1946).

Dragavtsev, A. P. Apple of Mountain Habitats; Ecology and Features of its Culture as Exemplified by Trans-Ili Ala-Tau (in Russian). **Akad. Nauk SSSR**, 253 p. (1956).

Dubrovskaya, N. I. Age Variability and Reservation of Plants (in Russian). **Izd. Akad. Nauk SSSR** (1961).

Dunin, M. S., and Kolesnikov, V. A. Control of Rosette and Small Leaf Disease in Apples (in Russian). **Sadovodstvo**, 8, 355-360 (1962).

Friedrich, G., *et al.* Fruit Growing, 797 p. (1958).

Friedrich, G., and Schmidt, G. Investigations on the Assimilation of Apple, Pear, Cherry and Plum with a New Apparatus. **Archiv für Gartenbau**, VII Band, Heft 5/6, 321-346 (1959).

Fritzsche, R. Investigations on the Juvenile Forms of Apple and Pear, and Their Close Relation with Root-Stocks and the Breeding of New Variaties. **Ber. Schweiz.** Bot. Gesellsch, 58, 207 (1948).

Gardner, V. R., *et al.* The Fundamentals of Fruit Productions. N. Y. (1952).

Gardner, V. R., *et al.* Thinning the Apple Crop by Spray at Blooming. A prelim. report. **Proc. Amer. Soc. Hort. Sci.**, 37 (1939).

Gena, N. Architectonics and Growth of the Aerial Portion and Root System of Apple Trees, Grafted on Different Wildings (in Russian). **Izv. Timiryazev Akad.**, 1, 149-164 (1959).

Genkel, P. A. Physiology of Plants Along with Microbiology. **Uchpedgiz.**, Moscow, 536 p. (1962).

Genkel, P. A., and Oknina, E. Z. Diagnosis of Frost-Resistance of Plants Depending upon the Depth of Dormancy of Their Tissues (in Russian). **Izd. Akad. Nauk SSSR**, 35 p. (1954).

Gorbatyuk, D. O. Depth of Soil Cultivation in Bearing Orchards in Connection with the Development of Root System of Fruit Trees (in Russian). **Sborn. Nauchn. Trud. Umansk. Selskokh. Inst.**, 11 (1953).

Gruzdev, G. I. Qualitative Evaluation of Soils Usable for Orchards Based on Natural Conditions (In Russian). **Pochvovedeniye**, 5 (1960).

Gruzdev, G. I. Choosing a Location and Soil for an Orchard. Moscow, **Gosud. Izd. Selskokh. Liter.**, 119 p. (1956).

Gunar, I. I. and Kalinkevich, M. I. Regulation of Blooming and Fruit Bearing in Apple Trees with Chemical Means. **Izv. Timiryazev Selskokh. Acad.**, 1, 22-41 (1961).

Guseva, E. I. Biological Methods of Studying Regularity of Growth and Bearing of Citrus and Other Fruit Plants (in Russian). **Trud. Instit. Physiol. Akad. Nauk SSSR**, 7, No 1 (1951).

Gushin, M. Yu. Character of Root Growth of Fruit Trees in Different Times of Year Depending on Soil Conditions (in Russian). **Trud. Ukr. Nauchno-issled. Inst. Plod.**, Kiev (1941).

Harley, C. P., *et al.* A Study of Correlation Between Growth and Certain Nutrient Reserves in Young Apple Trees. **Proc. Amer. Soc. Hort. Sci.**, 53 (1949).

Hatton, R. G. Rootstock Work of East Malling. **Sci. Hort.**, 7 (1939).

Hoagland, D. R. Minute Amounts of Chemical Elements in Relation to Plant Growth. **Science**, 91 (1940).

Hoffman, F. W. Yield Relationships on Terminal Growths in York Imperial Apples. **Proc. Amer. Soc. Hort. Sci.**, 30 (1934).

Hoffman, M. B., *et al.* A Comparison of Two Types of Materials for the Chemical Thinning of Apples. **Proc. Amer. Soc. Hort. Sci.**, 49, 37 (1947).

Ivanov, S. M. To the Question of the Interrelation of the Leaves and Roots in Perennial Plants (in Russian). **Dokl. Akad. Nauk SSSR**, 88, 3 (1953).

Iwasaki, T. Studies on the Control of Alternate Bearing in Citrus. IV. The Effect of Fruit Thinning on the Control of Alternate Bearing. **J. Jap. Soc. Hort. Sci.,** 30 (1961).

Iwasaki, T. Studies on the Control of Alternate Bearing in Citrus. V. Effect of Harvesting Date on the Number of Flowers and Shoot Growth in the Following Year. **J. Jap. Soc. Hort. Sci.,** 30, 2 (1961).

Kabluchko, G. A. Fruit-Growing in Moldavian SSR (in Russian). **Gosizdat Moldav.,** 222 p. (1955).

Kanivets, I. I. Soil Condition and the Growth of Apple Trees (in Russian). **Gosizdat Moldav.,** 496 p. (1958).

Karamysheva, V. I. Analysis of the Pollen of Different Varieties and Species of Apple Trees (in Russian). **Trud. aspir. and molod. nauchn. sotr., Vsesoyuzn. Inst. Rasten.,** 247-258 (1961).

Karpov, G. K. Biological Basis of Pruning of Apple Tree (in Russian). **Trud. Zentral. Genetich. Laborat.,** VI (1958).

Kazarian, V. O., and Balgazian, N. V. The Ontogenetic Variability of the Direction of Movement of Nutritive Plastic Substances in Plants (in Russian). **Akad. Nauk SSSR,** 103 (1955).

Kobel, F. Fruit Growing on Physiological Basis. Berlin, 348 p. (1954).

Kolesnikov, V. A. The Root System of Fruit Trees (in Russian). **Nauchno-agronom. zhurnal,** 3, 211-229 (1924).

Kolesnikov, V. A. The Dying Off of Rootlets of Fruit Trees (in Russian). **Nauchno-agronom. zhurnal,** 11 (1924).

Kolesnikov, V. A. Parthenocarpy and Selfpollination in Fruit (in Russian). **Trud. Salgir. Pomolog. St.,** 2 (1927).

Kolesnikov, V. A. The Root System of Fruit Tree Seedlings and the Dying Off of Rootlets of Fruit Trees. **Journ. of Pom. and Hort. Sci.,** 8, 3, 197-209 (1930).

Kolesnikov, V. A. The Fruit Growing of Crimea (in Russian). **Krymizdat,** 37 p. (1951).

Kolesnikov, V. A. Knowledge and Control of the Plant Root and Top Systems Ensure High Yields of Apple Trees. **The Report of the 14th Intern. Hort. Congr.,** Netherlands, 906-913 (1955).

Kolesnikov, V. A. The Uptake of Labelled Phosphorus from Superphosphate by Apple Trees as Affected by the Method and Depth of Application (in Russian). **Izv. Timiryaz. Selskokh. Akad.,** 3, 213-223 (1957).

Kolesnikov, V. A. The Root System of Fruit Trees and Soft Fruits (in Russian). **Vestnik Selskokh. Nauk,** 4, 64-71 (1958).

Kolesnikov, V. A. The Growth of Axial and Absorbing Roots of Top and Small Fruit Plants Throughout Their Annual Life Cycle (in Russian). **Izv. Timiryaz. Selskokhoz. Akad.,** 1, 127-148 (1959).

Kolesnikov, V. A. Root System of Tree and Soft Fruit and Methods of Studying. **Izdat. Selskokh. Liter.,** 190 p. (1962).

Kolesnikov, V. A. The Dimension and Distribution of the Root System in the Apple Tree Depending on Different Factors (in Russian). **Izv. Timiryaz. Selskokhoz. Akad.,** 2, 85-100 (1963).

Kolesnikov, V. A., and Palkevi, I. Dynamics of Uptake and Distribution of Radiophosphorus in Relation to the Phase of Growth and Development of Above- and Underground Systems of Apple Tree (in Russian). **Izv. Timiryaz. Selskokh. Akad.**, 3, 132-146 (1963).

Kolomiyets, I. A. Conditions of Development of Fruit and Wood Buds of Apple Tree (in Russian). **Trud. Inst. Physiol. Rast. im. K. A. Timiryazeva**, 8, 2 (1954).

Kolosov, I. I. Absorptive Activity of Root Systems of Plants (in Russian). **Izdat. Akad. Nauk SSSR**, 386 p. (1962).

Kovalyov, N. V. Principal Regularity of Ecological Differentiation of Fruit Plants (in Russian). **Dokl. Vses. Akad. Selkokh. Nauk.**, 1 (1940).

Kovtun, I. M. Individual Development of Pear Seedlings (in Russian) **Ukr. Nauchno-issled. Institut Plod., Nauchn. trud.**, 33 (1954).

Krasilnikov, N. A. Microorganisms of the Soil and Higher Plants (in Russian). **Akad. Nauk SSSR**, 462 p. (1958).

Krenke, N. P. Theory of the Senescence and Rejuvenation of Plants and Their Practical Application (in Russian). **Selkhozgiz.**, 225 p. (1940).

Krenke, N. P. Regeneration of Plants (in Russian). **Izd. Akad. Nauk SSSR**, 672 p. (1950).

Krestnikov, A. D. Some Age-Changes of the Root System of Apple Tree (in Russian). **Dokl. Timiryaz. Selskokh. Akad.**, 98 (1964).

Kursakov, G. A. Morphological Peculiarities of Root Grafting of Apple Tree (in Russian). **Agrobiol.**, 3 (1959).

Kursanov, A. L. Root System of Plants as an Organ of Metabolism (in Russian). **Izv. Akad. Nauk SSSR, Ser. biol.**, 6 (1957).

Kuvshinov, I. S., *et al.* Economics of Socialist Agriculture (in Russian). **Izd. Selskokh. Liter.**, Moscow, 664 p. (1963).

Kvaratskhelia, T. K. To the Question of the Biology of the Root System of Fruit Trees (in Russian). **Izd. Sukhumi**, 104 p. (1927).

Lange, K. P. Protection of Bark of Fruit Trees from Frost Injury (in Russian). **Sad i Ogorod**, 1 (1949).

Lecrenier, A., Dermine, E. Fertilization of the Fruit Trees. **Fruits at Prim., Afrique Nord**, 25, **Bull. Hort.**, 7 (1955).

Leopold, A. C. The Role of Growths Substances in Flowers and Fruits. **Canad. Journ. Bot.**, 40, No 5, 745-755 (1962).

Levitt, J. The Hardening of Plants, N. Y. (1956).

Loomis, W. E. The Translocation of Nitrogen in Woody Plants. **Proc. Amer. Soc. Hort. Sci.**, 32, 61-64 (1935).

Luckwell, L. C. Plant Hormone Research at Long Ashton. **Science and Fruit**, 110 (1953).

MacDaniels, L. H. Some Anatomical Aspects of Apple Flower and Fruit Abscission. **Proc. Amer. Soc. Hort. Sci.**, 34 (1937).

Magness, J. R., Overley, F. L., and Luce, W. A. Relation of Foliage to Fruit Size and Quality in Apples and Pears. **Wash. Agr. Exp. Sta. Bull.**, 249 (1931).

Magness, J. R., *et al.* Apple Tree Response to Nitrogen Applied at Different Seasons. **J. Agr. Res.**, 76, 1 (1948).

Makarova, N. A. The Influence of Microelements on the Growth, Development and Carbohydrate Metabolism in Lemon Trees (in Russian). **Eksperim. Botanika**, 1, 7 (1956).

Maliga, P., and Tamási, I. The Root Formation of Walnut Trees in Sandy Soil (in Hungarian). **Kert szöl. Föisk. Evk.**, 21 (1957).

Michurin, I. V. What are the Possible Ways of Acclimatization of Plants (in Russian). **Sad i Ogorod**, 2 and 3 (1905).

Michurin, I. V. Collected Works, 3, 476 p. (in Russian). Selkhozgiz (1948).

Miroshnikov, I. P., and Bolton, L. V. Influence of Fruit and Blossom Thinning on Fruit Production, Growth and Fruit Bud Formation (in Russian). **Trud. Krymsk. Plod. St.**, 7, 2, 81-132 (1939).

Misterhaze, O. I. Influence of Pollination in Apple Tree on Yield and Beginning of Bearings. **Sbornik Opil. Selskokh. Ras. Pchelami.**, 3, 372-377 (1960).

Modlibowska, I., and Rogers, W. S. Freezing of Plant Tissues Under the Microscope. **Journ. of Exp. Bot.**, 6, 18 (1955).

Muromtsev, I. H. On Dynamics of the Development of Absorbing Roots of Apple Tree (in Russian). **Vestnik Plodovoyagodn. Kult.**, 2 (1940).

Muromtsev, I. A. The Root Hair of the Apple Tree (in Russian). **Dok. Vses. Selskokh. Akad. im. V. I. Lenina**, 7 (1948).

Muromtsev, I. A. The Selfthinning of the Root System of Plants (in Russian). **Izv. Akad. Nauk SSSR, Ser. biol.**, 3 (1953).

Muromtsev, I. A. The Reaction of Root Growth to Changes in Temperature (in Russian). **Tr. Plodoov. Inst. im. I. V. Michurina**, 9 (1956).

Muromtsev, I. A. Development and Activity of Roots in the Normal and Insufficient Aeration (in Russian). **Ibid.**, 8 (1959).

Muromtsev, I. A. The Frost-Resistance of the Absorbing Roots of Fruit Trees (in Russian). **Ibid.**, 10 (1959).

Muromtsev, I. A. Soil Temperature and Growth of Roots (in Russian). **Fiziol. Rast.**, 9 (1962).

Muromtsev, I. A. The Root Hairs of Fruit Trees (in Russian). **Tr. Plodoov. Inst. im. I. V. Michurina**, 14, 25-41 (1962).

Muromtsev, I. A. The Active Part of Root System of Fruit Trees (in Russian). **Thesis**, Moscow.

Nightingale, G. T. Ammonium and Nitrates Nutrition of Dorman Delicion Apple Trees at 48 F. **Bot. Gaz.**, 95, 437-452 (1934).

Oganesian, A. P. The Influence of Ground Water on the Development of Fruit Plants (in Russian). **Sad i Ogorod**, 5 (1950).

Oland, K. Nitrogenous Reserves of Apple Trees. **Physiol. Plant.**, 12, 594 (1959).

Overcash, J. P., and Loomis, N. H. Prolonged Dormancy of Pear Varieties Following Mild Winters in Mississippi. **Proc. Amer. Soc. Hort. Sci.**, 73, 88-91 (1959).

Passecker, F. Young and Adult Forms of Apricot and Other Fruit Plants. **Die Gartenbauwis.**, 14, 614 (1940).

Passecker, F. Regeneration of Mature Woody Plants by Vegetative Propagation. **Deut. Bot. Gesell. Ber.**, 74(9) (1961).

Patamina, N. O., and Shmigel, V. N. The Method of Improving the Biological Quality of Pollen (in Russian). **Thesis** (1960).

Peniazek, S., and Wisniowska, I. Studies on the Winter Rest Period of Antonovka's Seedlings. **Exper. Work of the Institute of Pomology**, Skierniewice-Poland, 114, 130-148 (1958).

Petrov, A. V. The Development of Apple Shoots (in Russian). **Dok. Mosk. Selskokh. Akad. im. K. A. Timiryazeva**, 26 (1956).

Petrovskaya, T. P. The State of Dormancy in Fruit Buds of Woody and Bushy Plants (in Russian). **Trud. Inst. Physiol. Akad. Nauk SSSR**, 9 (1955).

Piskarev, V. I. Germinating Pome and Stone Fruit Seeds Without a Dormant Period (in Russian). **Sci. Fruit Growing**, Michurinsk, 5 (1938).

Poplavskaya, T. K. The Peculiarities of Apple Trees Developing from Buds Taken from Different Positions in Crown of Maternal Tree (in Russian). **Tr. Zentr. Genet. Labor. im. I. V. Michurina**, 6 (1958).

Popov, V. P. The Rest-Period of Perennial Plants (in Russian). **Meteorol. i Gidrol.**, 7 (1939).

Potter, G. F., and Phillips, T. G. Composition and Fruit Bud Formation in Non-Bearing Spurs of the Baldwin Apple. **New Hampshire Agric. Exper. Sta. Techn. Bull.**, 42 (1930).

Pryanishnikov, D. N. On Disintegration of Proteinous Material at the Time of Germination. Moscow (1895).

Priymak, A. K. Selective Relation of the Roots to the Fertilizers (in Russian). **Sad i Ogorod**, 10 (1951).

Protsenko, D. F. The Frost-Resistance of Fruit Plants of USSR. **Izd. Kiev Univers.**, 391 p. (1958).

Radionov, A. P. Experimental Study of the Phase of Vernalization in Woody Plants (in Russian). **Ukr. Nauchno-issled. Inst. Plodov.**, 33 (1954).

Rogers, W. S. Root Studies. VIII. Apple Root Growth in Relation to Rootstock, Soil, Seasonal and Climate Factors. **Journ. Pom. and Hort. Sci.**, 17, 2 (1939).

Romanova, A. T. Anatomical and Morphological Changes of Fruit and Wood Buds of Apple in the Process of Their Development (in Russian). **Sborn. Nauchn. Rabot, Ukr. Nauchno-issled. Inst. Sadov.**, 34 (1959).

Rudenko, I. S. The Development of Fruit Buds of Apple Tree (in Russian). **Izd. Shtiinza**, Kishinev, 119 p. (1960).

Ryabov, I. N. The Selection of Varieties of Apple and Pear for Their Mixed Planting (in Russian). **Sborn. Vopros. Yuzhn. i subtrop. plodov.** Selkhozgiz, Moscow (1953).

Ryabakov, A. A. Biology of Fruit and Bush Plants (in Russian). **Izd. Akad. Nauk Uzbek. SSR**, 416 p. (1956).

Rytov, M. V. General Studies on Cultivated Plants (in Russian). Moscow (1896).

Sabinin, D. A. Physiological Principles of Plant Nutrition. Moskva, **Akad. Nauk SSSR,** 512 p. (1955).

Sadovski, A. Efficiency of Different Ways of Before Planting Plowing in the Conditions of Moscow Region. **Izv. Timiryazev. Selskokh. Akad.,** 6 (1961).

Schitt, P. G. The Study of Growth and Development of Tree and Soft Plants. **Selkhozizdat,** Moscow, 447 p. (1958).

Schitt, P. G., and Metlitsky, Z. A. Fruit Growing (in Russian). **Selkhozizdat,** Moscow, 511 p. (1940).

Sergeenko, V. M., *et al.* Preliminary Results of Research Studies Directed Towards Elimination of Biennial Bearing in Apple Orchards (in Russian). **Trud. Krymsk. Plod. St.,** 2, 3-80 (1939).

Sergeyev, L. I. Biological Analysis of Current Year Cycle of Development of Wood Plants. **Dokl. Akad. Nauk SSSR, Nov. ser.** XXI, No 1 (1950).

Sergeyeva, K. A. Development of Fruit Buds in Different Species of Persimmon (Diospyros). **Glav. Bot. Sad.,** 13, 24, Moscow (1956).

Sholokhov, A. M. Winter-Hardiness of Apricot in Relation to the Morphologenesis of Fruit Buds (in Russian). **Soveshchan. po Morfogenezu Rast. Trud.,** 1(2) (1961).

Sidorenko, P. G. Qualitative Changes of Root System in the Process of Individual Development of Fruit Plants. **Avtoreferat,** Kiev (1954).

Skoog, F. Zinc and Auxin in Plant Growth. **Am. J. Bot.,** 27, 939 (1940).

Sokolova, E. P. The Period of Receptivity of the Stigmas to the Pollination in Tree and Soft Fruits (in Russian). **Tr. plodoov. Inst. im. I. V. Michurina,** 7 (1953).

Solovyeva, M. A. Influence of Water Content and the Fertilization on the Frost Resistance of Fruit Trees (in Russian). **Sborn. Dostizh. nauchn. uchr. po plod. i vinogr. Vses. Akad. Selskokh. Nauk im. V. I. Lenina,** 157-168 (1959).

Spivakovsky, N. D. Influence of the Forms of Nitrogen on the Growth of Apple Tree and Development of Fruit Buds (in Russian). **Dok. Vses. Akad. Selskokh. Nauk im. V. I. Lenina,** 2 (1949).

Spivakovsky, N. D. Character of Phosphorus Distribution Among the Different Organs of an Apple Tree. Moscow, **Trudi Fiziol. Rast. Izd. Akad. Nauk SSSR** (1958).

Stoichkov, I. Relation Between the Phenological Peculiarities of Apple Varieties and Their Susceptibility to Alternate Bearing (in Russian). **Mezhdun. Selskokh. Journ.,** 5, 72-78 (1959).

Tamaczi, I. Examination of the Root System of Apricot Trees Growth on Various Understocks. **Ann. Acad. Hort. et Viticol,** 22, Budapest (1958).

Tanaka, J. 1935. Investigations of the Time of Transplanting of Young Fruit Trees. **Communications from Hort. Inst. Taihoku, Imp. Univ.,** 3 (1932).

Tarasenko, M. T. Some Peculiarities of Individual Development of Fruit Trees (in Russian). **Dokl. Timiryazev Selskokh. Akad.**, 40 (1959).

Tarasenko, M. T., and Stefan, N. N. Rooting Softwood Cuttings of Cherry and Plum in Relation to the Growth Phases and Development of the Shoots. **Izv. Timiryazev. Selskokh. Akad.**, 3 (1960).

Tarasov, V. M. Effect of Zinc on Rosette and Small-Leaf Disease of Apples in the Volga Area. Moscow. **Dokl. Selskokh. Akad. im. K. A. Timiryazeva**, 77 (1962).

Tashmatov, L. T. The Cultivation of the Jujube in the Middle Asia. **Subtrop. Kult., Selkhozgiz.** Moscow (1959).

Thomas, W. The Seat of Formation of Aminoacids in Pyrus Malus. **Science**, 66, 115-116 (1927).

Thompson, C. R. Biennial Bearing of Apple Trees. Principles Governing its Treatments (1940).

Tsuin Shen. The Influence of Leaf-Fruit Ratio on Alternate Bearing in the Apple. **Proc. Amer. Soc. Hort. Sci.**, v. 38 (1941).

Tumanov, I. I. Principal Achievements of Soviet Science in Studying the Frost-Resistance of Plants. **Izd. Akad. Nauk SSSR**, Moscow, 54 p. (1951).

Tumanov, I. I., and Gareyev, E. Z. Influence of the Organs of Bearing on Plant (in Russian). **Trud. Inst. Physiol. Rast. SSSR**, 7 (1951).

Tupitskin, D. I. Biology of the Development of Fruit Buds of Plums in the Conditions of Uzbekistan. **Avtoreferat**, Tashkent (1955).

Turkov, V. D. Certain Peculiarities of Growth and Development of the Fruit Buds in Cherries (in Russian). **Dokl. Selskokh. Akad. im. K. A. Timiryazeva**, 48, 165-171 (1959).

Turovtsev, N. I. Some Morphological and Physiological Peculiarities of Apple Tree Shoots Arising from Adventitious Buds (in Russian). **Bull. Zentr. Genet. Labor. im. I. V. Michurina**, 9-10, 39-45 (1960).

Tuz, A. S. Flower Anomalies in Peach and Apricot During Secondary Flowering (in Russian). **Bot. Zhurn.**, 45 (1960).

Ursulenko, P. K. Physiological Basis of Soil Management for Obtaining Annual Yields and High Frost-Resistance in Apple Tree (in Russian). **Bull. Nauchnotechn. inf. Instit. Sadovod. im. I. V. Michurina**, 1 (1956).

Ursulenko, P. K. Application of Labelled Phosphorus in Studying Foliar Nutrition of Fruit Plants. **Izd. Akad. Nauk SSSR**, Moscow (1957).

Vasiliev, I. M. Wintering of Plants. Moscow. **Akad. Nauk SSSR** (1956).

Vavilov, N. I. The Centres of the Origin of Cultivated Plants (in Russian). **Trud. po Prikl. Bot.**, 16, 2 (1926).

Velkov, V. Achievements in Controlling Irregular Bearing. **Vish. Selskokh. Inst. v Plovdiv**, 3 (1955).

Viktorov, S. V. Multiplication of Cells in the Buds of Bushes in Winter (in Russian). **Dokl. Akad. Nauk SSSR**, 39, 6 (1943).

Vinograd, D. I. Development of Root System of Apricot in the First Vegetative Period After Planting (in Russian). **Trud. Dagest. Selskokh. Inst.**, 1 (1939).

Vinokur, R. L. Influence of Temperature of Root Environment on the Activity of Roots, Transpiration and Photosynthesis of Leaves in Lemon Plants (in Russian). **Fiziol. Rast.**, 4 (1957).

Voronchikhina, L. N. Correlation Between Growth of Root and Above-Ground System of Gooseberry. Moscow. **Dokl. Selskokh. Akad. im. K. A. Timiryazeva**, 22 (1956).

Wallace, T. Some Aspects of the Mineral Nutrition of Horticultural Plants. **Long Ashton Res. St. Univ.**, Bristol (1953).

Williams, C. E. Fall Fertilization of Peach Trees in the Sand Hills. **N. C. Agr. Exp. Sta. Bull.**, 321 (1939).

Yefeikin, A. K. The Role of Meristem in the Phanerogam Ontogeny (in Russian). **Bot. zhurn.**, 42, N3 (1957).

Yelmanov, S. I. The Winter Development of Fruit Buds of Peach and Apricot (in Russian). **Trud. Gos. Nikit. Bot. Sada.**, 29, 251-268 (1959).

Yeremeyev, G. N. The Role of Root System in the Stableness of Plants to Surplus and Deficient Soil Moisture (in Russian). **Sotsialist. rasteniev.**, 18 (1936).

Yevdokimova, T. P. Interrelation of Root System and Aerial Portion in Apple Trees (in Russian). **Izv. Timiryazev. Selskokh. Akad.**, 62 (1955).

Yurtzev, V. N. Peculiarities of Development of Adventitious Buds in the Light of Works of I. V. Michurin. **Izv. Timiryazev. Selskokh. Akad.**, 2 (1955).

Zelenskaya, E. D. On the Influence of Pruning on the Changes in Biochemical Composition of Apple Trees (in Russian). **Dokl. Vses. Selskokh. Akad. im. V. I. Lenina**, 10 (1949).

Zelenskaya, E. D. Application of Radioactive P^{32} in Studying the Methods of Fertilization of Fruit Trees. **Izd. Akad. Nauk SSSR**, Moscow (1957).

Zgurovskaya, L. N., and Tselniker, U. D. Effect of Watering After a Prolonged Drought on the Condition and Transpiration of Roots of Tree Species in Derkul' Steppe (in Russian). **Fiziol. Rast.**, 2, 346-353 (1955).

Zheleznov, N. I. On the Development of the Buds in Winter. **Petrovskaya Akad.** Moscow (1851).

Zhukovsky, P. M. The Present State of the Study of Cultivated Plants in the USSR and Abroad. **Byuro Prikl. Bot., Genet. i Selekz.**, Leningrad (1929).

Zhukovsky, P. M. Cultivated Plants and Their Relatives (in Russian). **Sovet. nauka**, Moscow 592 p. (1950).

TO THE READER

Peace Publishers would be grateful for your comments on the content, translation and design of this book. We would also be pleased to receive any other suggestions you may wish to make. Our address is: 2, Pervy Rizhsky Pereulok, Moscow, U.S.S.R.

Printed in the Union of Soviet Socialist Republics

V. A. Kolesnikov was an undergraduate at the Timiryazev Agricultural Academy in Moscow when he first became absorbed in the study of fruit tree roots. That was in 1920. Four years later he published the first results of his research. By then he had unearthed certain correlations in the growth of root systems. The most fruitful of these related to the average root length of seedlings which the young research worker found to be constant for each species no matter what environment it grew in. Later on he used this root coefficient to develop a new and efficient method of root study—the so-called "free monolith" method, which is now extensively used in the U.S.S.R. and in some other countries. The author has also established that new root formation is always attended by the dying off of roots, a phenomenon which he termed root shedding. The investigations conducted by the author in Moscow Region, and in subsequent years in the Crimea and Krasnodar Territories enabled him to advance a number of cultural recommendations—on under-tree ploughing, the application of fertilizers, the time of watering, etc.,